Calhoun: The NPS Institutional Archive

DSpace Repository

Theses and Dissertations | 1. Thesis and Dissertation Collection, all items

1987

Techniques for organizing and implementing a Naval base productivity improvement.

Nicolaou, Chris George.

http://hdl.handle.net/10945/22541

Downloaded from NPS Archive: Calhoun

http://www.nps.edu/library

Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY CALIFORNIA 93943-5002

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

TECHNIQUES FOR ORGANIZING AND IMPLEMENTING A NAVAL BASE PRODUCTIVITY IMPROVEMENT

by

Chris G. Nicolaou

March 1987

Thesis Advisor: D.E. Neil

Approved for public release; distribution unlimited

Prepared for:
Naval Postgraduate School
Code 55
Monterey, CA 93943

T233311

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved to public release; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b OFFICE SYMBOL (If applicable) Code 55	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000	7b ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000
8a NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
TECHNIQUES FOR ORGANIZING AND IMPLEMENTING A NAVAL BASE PRODUCTIVITY IMPROVEMENT

12 PERSONAL AUTHOR(S)
Nicolaou, Chris G.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month Day)	15 PAGE COUNT
Thesis	FROM _____ TO _____	March 1987	94

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Naval Bases; Productivity

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

During recent years the concept of increasing productivity has generated a great deal of discussion in business and economic corcles especially in the Armed Forces of each Nation. This interest has motivated research into the area of productivity measurement. The purpose of this study is to develop a model for measuring productivity and to present techniques for organizing and implementing a workshop of a Naval base productivity.

The results of this research serve a wide variety of needs such as:

* Human resource allocation and effective control over a Navy workshop maintenance facility.
* Personnel performance improvement.
* A set of methods for measuring productivity.

Products of this study are the following:

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL D. E. Neil	22b TELEPHONE (Include Area Code) 408-646-2419 22c OFFICE SYMBOL 55Ni

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

* Development of a general productivity measurement model at a firm level which can be modified and applied to the operation of a workshop in a Naval Base.

* Identification of critical factors that are required in an effective productivity measurement system.

Finally, it must be noted that a successful productivity measurement is the representative indicator for the future treatment and success of every organization.

Approved for public release; distribution is unlimited

Techniques for Organizing and Implementing a Naval Base Productivity Improvement

by

Chris George Nicolaou
Lieutenant Commander, Hellenic Navy
B.S., Hellenic Naval Academy, 1971

BACHELOR OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1987

ABSTRACT

During recent years the concept of increasing productivity has generated a great deal of discussion in business and economic circles especially in the Armed Forces of each Nation. This interest has motivated research into the area of productivity measurement. The purpose of this study is to develop a model for measuring productivity and to present techniques for organizing and implementing a workshop of a Naval base productivity.

The results of this research serve a wide variety of needs such as:

* Human resource allocation and effective control over a Navy workshop maintenance facility.
* Personnel performance improvement.
* A set of methods for measuring productivity.

Products of this study are the following:

* Development of a general productivity measurement model at a firm level which can be modified and applied to the operations of a workshop in a Naval base.
* Identification of critical factors that are required in an effective productivity measurement system.

Finally, it must be noted that a successful productivity measurement is the representative indicator for the future treatment and success of every organization.

TABLE OF CONTENTS

I. INTRODUCTION.....11

II. BACKGROUND.....15

A. DEFINITIONS.....15

1. The Economist's View.....18

2. The Engineer's View.....18

3. The Accountant's View.....18

4. The Industrial/Organizational Psychologist's View.....19

5. The Manager's View.....20

6. Effectiveness and Productivity.....20

7. Quality of working Life and Productivity.....22

III. PRODUCTIVITY PROBLEM IN THE NAVAL BASES.....24

A. NAVAL BASES.....24

B. STATEMENT OF THE PROBLEM.....30

IV. MEASURING PRODUCTIVITY 33

A. GENERAL MEASUREMENT ISSUES 34

1. Measurement Definition and Benefits.....34

2. Levels of Measurement.....35

B. THE ROLE OF MEASUREMENT IN PRODUCTIVITY IMPROVEMENT 36

C. METHODS OF MEASUREMENTS.....40

1. Efficiency Measurement.....40

a. Physical Quantity Input and Output Microlevel.....43

b. Physical Quantity Input and Output Macrolevel.....44

c. Price Outputs and Physical Quantity Inputs....44

d. Physical Quantity Outputs and Price Inputs....45

e. Outputs and Inputs in Price Terms....46

2. Effectiveness Measurement....46

a. Quality....47

(1) Design....48

(2) Equipment....49

(3) Materials....49

(4) Scheduling....50

(5) Performance....50

b. Quantity....50

c. Timeliness....51

3. The Study of Time....51

4. Work Sampling....56

5. Systems of Standards Data....58

6. Predetermined Time Systems....63

7. Physiological Measures....63

V. PRESENTATION OF THE MODEL....65

A. COMMENTS ON THE AMERICAN PRODUCTIVITY CENTER (APC)....65

B. THE PRODUCTIVITY INDEX....66

C. THE PRICING RECOVERY INDEX....67

D. THE COST EFFECTIVENESS INDEX....68

E. ANALYSIS OF VARIANCE....70

VI. REQUIRED FACTORS FOR THE APC MODEL....72

A. OBJECTIVES OF THE WORKSHOPS.....71
1. Workshop's Maintenance Goal.....72
2. Main Objectives of Workshops.....73
3. Other Workshop's objectives.....74
B. DETERMINATION OF AVAILABLE INPUTS.....75
1. Labor.....75
2. Capital.....76
3. Materials.....78
4. Energy Resources.....78
5. Miscellaneous Inputs.....78
C. DETERMINATION OF OUTPUTS.....79
D. SUMMARY.....80
VII. CONCLUSIONS AND RECOMMENDATIONS.....83
A. CONCLUSIONS.....83
B. APPLICATION IN WORKSHOP MAINTENANCE FACILITY.....85
LIST OF REFERENCES.....91
INITIAL DISTRIBUTION LIST.....93

LIST OF TABLES

I. WORLDWIDE PRODUCTIVITY COMPARISON.....12

II. MANAGER'S DEFINITION OF PRODUCTIVITY.....21

III. PRODUCTIVITY MEASUREMENT METHODS.....41

IV. COMPUTATION OF LABOR PARTIAL INDEX.....45

V. SAMPLE SIZES FOR 95 PERCENT CONFIDENCE.....59

VI. TIME STUDY DATA FOR BOILER-MAKER SECTION'S DATA BASE..61

LIST OF FIGURES

1.1 Productivity Cycle.....13

2.1 General Productivity Concept.....16

2.2 Typical Production Function.....17

3.1 Typical Naval Base Organization.....25

3.2 Technical Section Organization.....28

4.1 Factors for Quality of Outputs.....48

4.2 Timing Devices.....55

4.3 Time vs. Inside Diameter.....62

4.4 Time vs. Outside Diameter.....62

6.1 Considered Input Elements for the APC Model.....77

6.2 General Considered Output Elements for a Productivity Measurement Model.....81

6.3 Considered Output Elements for the APC Model.....82

ACKNOWLEDGMENTS

These words fail to convey my unlimited appreciation to Dr. D.E. Neil who as a Thesis Advisor helped me so much with his closing supervision during this research report.

I also would like to express my appreciation to Dr. T. Mitchell for his support and assistance in my difficult work. Finally, I would also like to thank my wife, Mary, for her patience and encouragement throughout my academic career.

I. INTRODUCTION

Not many years have passed since the Advanced Nations began to be concerned with the concept of productivity and the creation of methods for its increase. This was necessary after the warning of the Bureau of Labor Statistics whose measurements indicated that productivity was declining at an alarming rate. Table I displays current data from the Bureau of Labor Statistics on the rate of growth productivity. Examination of Table I suggests a small percentage of increase in productivity for three countries during the decade of 70's, while remaining countries suffered a reduced in productivity. In the beginning of the decade of 80's all the mentioned countries demonstrated a decrease in productivity which if not stabilized could prove to be significant during the coming decade. [Ref. 1:p. 5]

Stopping this decline in productivity will not be easy. First, the concept of productivity must be clear; indeed the term itself has never really had a universally accepted definition. Second, in order to improve productivity, somehow productivity must be measured. This implied capability to measure and adjudge productivity, a concept which itself is unclear, is definitely easier said than done. The area of productivity improvement is receiving unprecedented attention these days, largely due to the fact that it is one of

TABLE I

WORLDWIDE PRODUCTIVITY COMPARISON

PRODUCTIVITY: ANNUAL PERCENTAGE INCREASE

DURING THE PERIOD	1960-66	1967-73	1974-80
CANADA	4.3	4.9	2.8
FRANCE	5.4	5.7	5.1
ITALY	7.3	6.6	3.3
JAPAN	8.5	10.0	4.2
WEST GERMANY	5.8	5.0	5.0
UNITED KINGDOM	4.1	3.8	0.6
UNITED STATES	4.2	2.9	2.1

Source: Bureau of Labor Statistics

the most effective weapons against inflation. Researchers, economists, industrial engineers, manufacturing engineers, statisticians, managers of all types and from all sizes of organizations, and many others have been paying more attention to the concept of productivity improvement, but a careful analysis, as shown in Figure 1.1, will show that this is only one part of the productivity cycle. This cycle of productivity is an on-going process for any organization which has a Productivity program and, once set in motion, keeps repeating itself. The first step of the Productivity cycle is productivity measurement, followed by evaluation, planning, and finally improvement. [Ref. 2:p. 10]

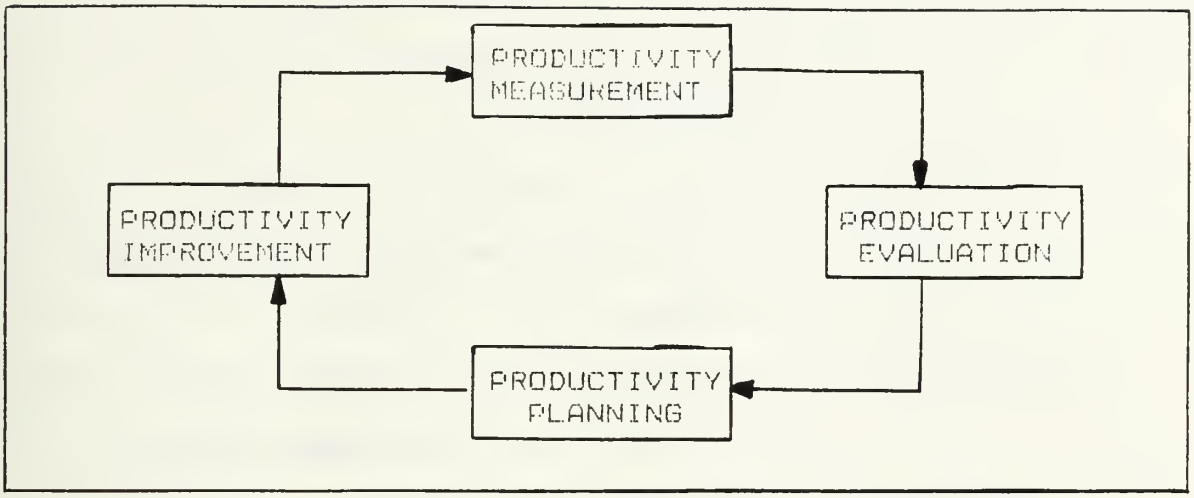

Figure 1.1 Productivity Cycle.

Emphasizing the need for productivity improvement, this thesis provides straightforward descriptions of the most traditional industrial engineering methods for measuring and improving productivity, in such a way that the researchers and managers who are working in the workshop of a Naval base have a good tool for organizing and improving productivity in their area.

To succeed all the above mentioned this thesis has seven chapters:

Chapter I Introduction

Chapter II Reviews definitions of productivity and contrasts them with definitions of organizational effectiveness and quality of working life.

Chapter III Analysis of the meaning of productivity in a military environment such as the Naval base.

Chapter IV Approaches for Measuring and Evaluating Productivity with emphasis to the workshops of a Naval base.

Chapter V Presents a general productivity model which can be adapted easily to the purposes of the workshops.

Chapter VI Describes all the required factors for the total productivity measurement model.

Chapter VII Summarizes the major conclusions from the preceding discussion to developing a productivity measurement methodology for use in Naval base workshops.

II. BACKGROUND

A. DEFINITIONS

Productivity is a subject that everyone has encountered in one form or another, but the exact meaning of the term is often badly confused. This section will refer to some of the most common definitions of productivity and help clarify the concept by contrasting it with two related concepts--organizational effectiveness and quality of working life. Productivity may be defined simply as a relationship of output to input, or the comparison of an input used in a process, such as man-hours of labor, units of capital, quantity of raw material, with the consequent output. "Productivity" is often confused with "Production". Production is only the numerator of the Productivity ratio. The inputs that went into the process are not considered.

1. The Economist's View

According to a leading productivity economist, [Ref. 1:pp. 7-8] Productivity is the relationship between output and its associated inputs when the output and inputs are expressed in real terms. This definition can be depicted as the ratio:

$$\text{Productivity} = \frac{\text{Output}}{\text{Inputs}}$$

This definition is developed from production theory which

attempts to explain the process by which inputs to an organization are transformed into products shown in Figure 2.1.

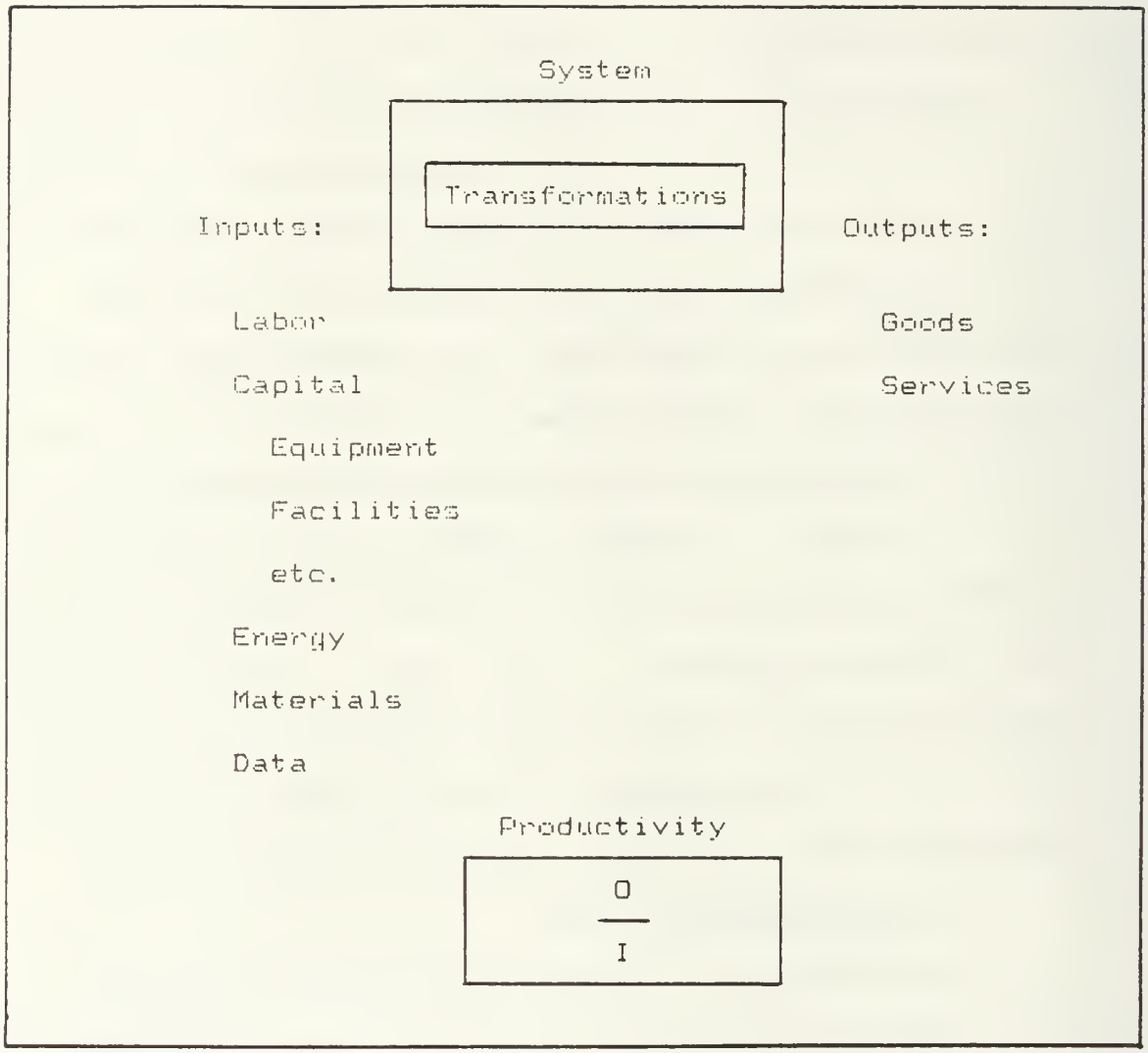

Figure 2.1 General Productivity Concept

The basic production function states that the volume of output (Q) is a function (F) of the volume of the basic productive factors. These are labor (L), capital (K),

intermediate products purchased from other firms (X) and the level of productive efficiency which changes over time (T).

$$Q = F(L, K, X, T)$$

Typically, a production function has the form shown in Figure 2.2 when only one input variable is present. From this function one can derive such productivity indices as labor productivity = Q/L, capital productivity = Q/K, etc. If all inputs are included in the denominator of the ratio we have what is called a "multi-factor" or "total factor" productivity ratio.

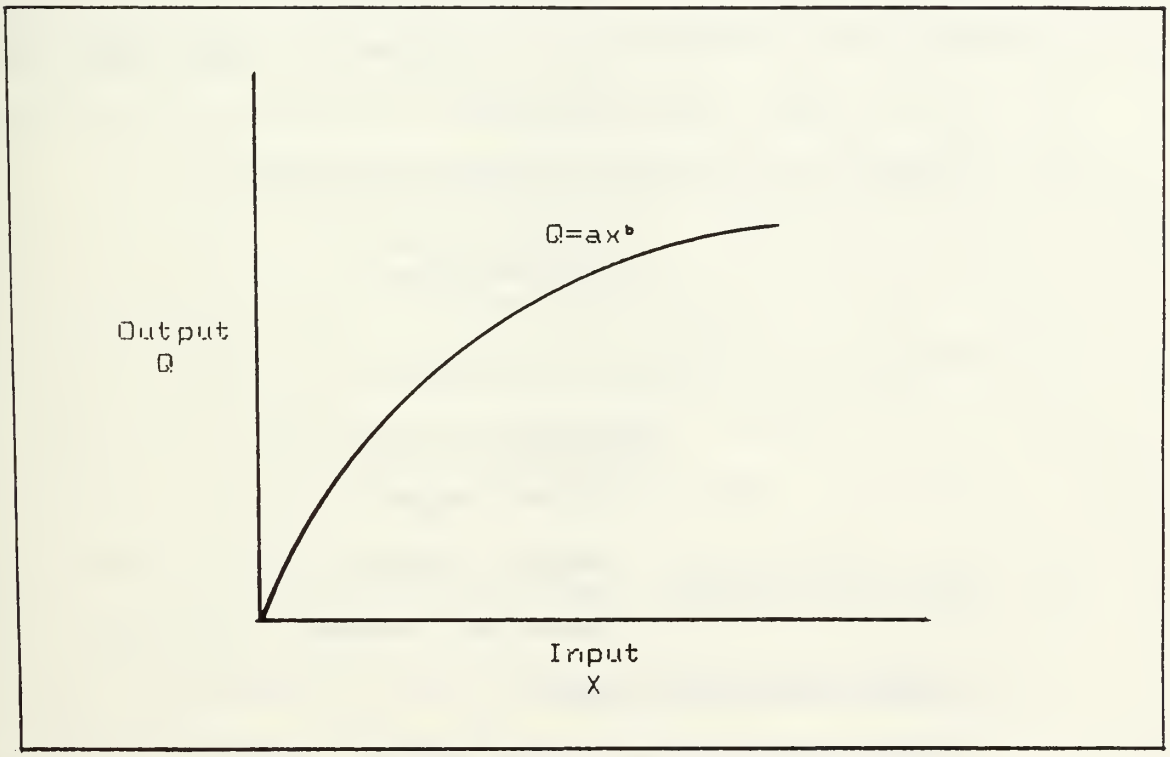

Figure 2.2 Typical Production Function

2. The Engineer's View

The engineer's definition of productivity differs from that of the economist [Ref. 1:pp. 8-10]. Conceptually, the engineering approach to productivity grows out of the "normal engineering expression for the efficiency of the machine".

$$\text{Efficiency} = \frac{\text{Useful Work}}{\text{Energy}} = 1$$

Thus, since output (useful work) is a result of input (energy supplied) in the physical sense, the engineer's ratio cannot be greater than unity. Considering productivity as basically synonymous with efficiency, the engineering approach leads to three definitions of productivity.

1. Generation of useful output from input

$$\left(\frac{\text{Useful output}}{\text{Input}}\right)$$

2. Efficiency of input utilization

$$\left(\frac{\text{Effective input}}{\text{Actual input}}\right)$$

3. Output Efficiency $\left(\frac{\text{Actual output}}{\text{Potential output}}\right)$

3. The Accountant's View

Accountants concern themselves with the financial performance of organizations. The "tools" for monitoring financial performance in organizations are financial ratios.

Many of these ratios resemble output/input product ratios and are the following:

1. Profit/Capital Employed
2. Profit/Sales
3. Sales/Capital Employed
4. Sales/Fixed Assets
5. Sales/Stocks
6. Sales/Employee
7. Profit/Employee

Since these are sales-based ratios they have less to do with production efficiency and more to do with factors in the marketplace. Therefore, they may be misleading if interpreted as productivity measures. [Ref. 1:pp. 9-10]

4. The Industrial/Organizational Psychologist's View

The concern of the industrial/organizational psychologist is with investigating human behavior in organizations. Productivity, defined as output/input, is a "results" oriented variable that is partially a function of behavior, but is also affected by other extraneous aspects of the work environment. Thus, as a criterion against which to judge the impact of various attempts to modify human behavior in organizations, productivity has not proven as useful as criteria which are defined in terms or worker behavior. [Ref. 1:pp. 11-12]

5. The Manager's View

In the United States the managers have a broad view of the meaning of Productivity. During a survey of two groups of managers, Chief Executive Officers (CEOs) and Industrial Relation Officers (IROs), approximately 2,450 questionnaires were mailed to CEOs and 950 to IROs. In the survey, managers were asked to indicate their agreement or disagreement with a number of possible statements concerning the meaning of productivity. The results are summarized in Table II.

Based on these responses, it appears that most of the managers polled would find either the economist's or engineer's definition of productivity to be too narrow. [Ref. 1:pp. 10-11]

6. Effectiveness and Productivity

The distinction between effectiveness and productivity remains confused. In attempting to clarify this relationship there appear to be three viewpoints expressed in the literature:

1. productivity as a dimension of the broader concept of effectiveness.
2. productivity as a broad concept which encompasses both efficiency and effectiveness.
3. productivity and effectiveness as being separate but related concepts.

TABLE II

MANAGER'S DEFINITION OF PRODUCTIVITY

Productivity definition includes:	% Agreeing
1. Quality as well as quantity	95
2. Output per manhour in one company or organization	90
3. Overall efficiency and effectiveness of the operation	88
4. Disruptions, "shrinkage," sabotage and other troubles even if they are difficult to measure	73
5. Rate of absenteeism and turnover as well as output	70
6. Customer or client satisfaction	64
7. Employee loyalty, morale, or job satisfaction	55
8. Ratio of output to input by industry or sector of the economy, but not by individual organization	22

Productivity in the private sector is usually defined (as suggested earlier) as a ratio of output per unit of input. This definition is deceptively simple, however. Disagreements still occur over many basic questions: Is it really possible to measure productivity? How do you take into account the variety of tasks within one job? How can you separate the contributions of staff hours from other inputs such as capital investment?

In the public sector, the definition of productivity encompasses two components, efficiency and effectiveness. Efficiency measurements assess the cost per unit of output. Usually quantitative in nature, efficiency measures typically use staff hours as the basis for input measures and quantity produced as output measures. A more sophisticated, but more difficult input measurement is total resource expenditures, which may include energy use, capital, investment, depreciation, overhead and other contributions inputs.

Thus, efficiency is usually thought of in terms of a ratio that reflects a comparison of some aspect of unit performance to the costs incurred for that performance and effectiveness is defined as the degree to which an organization achieves its goals. [Ref. 1:pp. 15-17]

7. Quality of Working Life and Productivity

Quality of working life is a concept which has almost as many definitions as organizational effectiveness.

One of them defines the quality of working life as follows:

> A worker can be said to enjoy a high quality of working life when he (a) has positive feelings towards his job and its future prospects, (b) is motivated to stay on the job and perform well, and (c) feels his working life fits well with his private life to afford him a balance between the two in terms of his personal values. [Ref. 3:pp. 69-70]

Another definition, states:

> the quality of working life as a set with four elements: security, equity, individuation, and democracy. [Ref. 4:pp. 4]

Either implicitly or explicitly, all of these approaches view quality of working life as conceptually separate from objective outcomes of the workplace such as productivity. The conclusion is that quality of working life and productivity are conceptually distinct but compatible concepts. Most would agree that productivity improvements frequently accompany improvements in quality of working life. The procedures taken by organizations to improve quality of working life may be very similar, or identical, to the procedures required to improve labor productivity. [Ref. 1:pp. 17-19]

III. PRODUCTIVITY PROBLEM IN THE NAVAL BASES

A. NAVAL BASES

The naval base is a very complex activity, whose main task is to maintain the combat capability of a ship at its highest level by performing corrective and preventive maintenance. When the ships return from exercises to the naval bases there are numerous functions to be completed such as fueling, ammunition receiving, maintenance and machinery repairing, electronic equipment and weapons systems repair.

Therefore, each naval base is composed of different divisions, each one specializing in the fulfillment of a certain task. The components of these divisions are workshops, store houses of spare parts, ammunition supply, missile installations and fuel-tanks all of which are staffed and equipped to fulfill the demands imposed by the jobs to be performed.

Figure 3.1 provides a graphical look of the construction in a Naval base. Under the Commander of a Naval base there are five subsections the combination of which complete it's task. The first one is the technical section the role of which is the repair of the ships in such a way is to be maintain combat capability at its highest level. Second, is the supply section. The mission of this section is to keep the

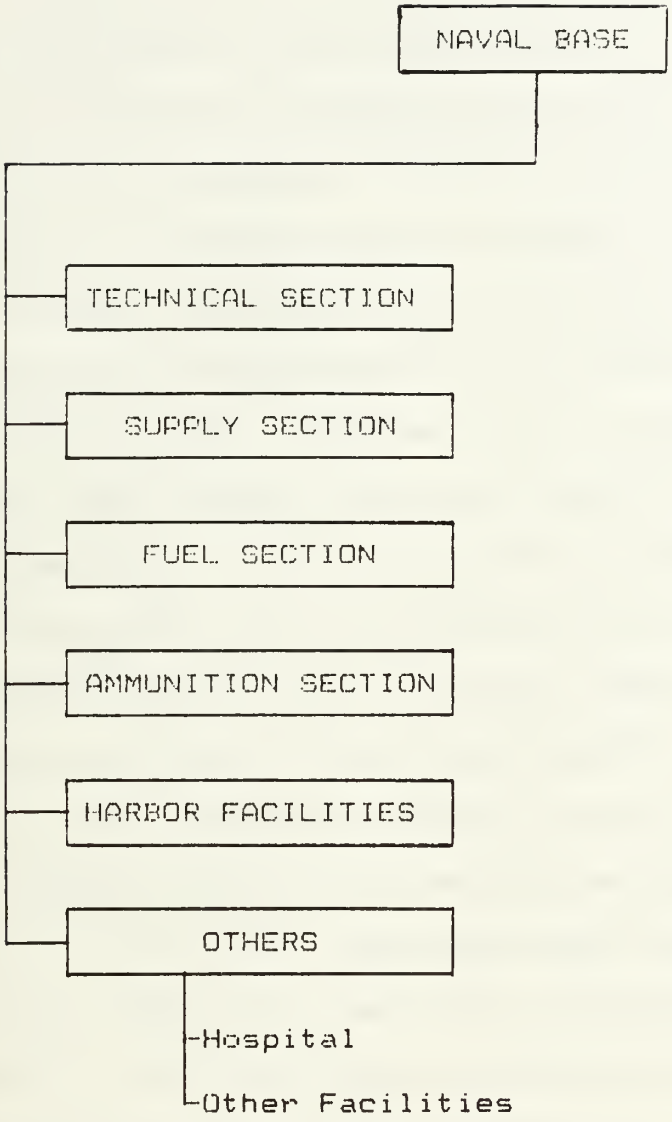

Figure 3.1 Typical Naval Base Organization

necessary stock of spares, stocks of food, etc., for the supply of the ships. This section must be kept in close collaboration with the workshop section for repair of machinery and electrical/electronic equipment. Third, the fuel section has the responsibility of maintain supply of all kinds of fuel and oil (e.g. fuel, mazut, kerozene-oil, paraffin oil, etc.). On the docks there are an adequate number of pipes with special connections from which the ships can be supplied with different types of fuel and oil. The ammunition supply section follows, and has the role to supply the ships with the different types of ammunition, but it has also the necessary technicians and equipment to repair shipboard armament. There is also, another section which is responsible for harbor facilities, such as the movement ships from one dock to another by tugs, etc. There are also, other available facilities such as the hospital which offers medical services to the staff of the Naval base, etc.

Since the complexity of modern warships is so great, as stated by Grahlman [Ref. 7:p. 11],

> A naval vessel is a totally integrated weapon system where space, weight and survivability are carefully balanced factors.

and becomes greater from day to day, the greater percentage of naval base activities belongs to the workshops. Each workshop can be expected to undertake jobs in only a specialized area of a particular system, such as machining, electrical work, pipefitting, sheet metal work, etc.

Figure 3.2 shows how the technical section is organized. Under the General Director there are six subdivisions. The Programming section is responsible for allocating the available resources according to ship requirements. The mission of the workshop section is to accomplish the different types of repairs by supporting the readiness of the ships and minimizing the cost. The electrical energy section has its own generators and compressors to supply the ships with electricity and compressed air. The chemical laboratory checks parts of the machines to perform the specifications and standards. The electrical/electronic section is responsible for repairs on electrical circuits, generators and electronic equipment. Finally, the design section divises plans for new construction and assesses ship system performance after modification. The jobs range from a single routine repair operation to an extensive full ship overhaul. There is negligible overlap in the area of specialization between shops of the same division. The workers of any workshop are often trained not only in certain specialized areas, but also for equipments for only a certain type of ship. There are workshops which demand that personnel have a high level of technical knowledge (e.g., electronics, weapons systems etc.) and other workshops have less demands (e.g., boilers, piping etc.). [Ref. 6:p. 8]

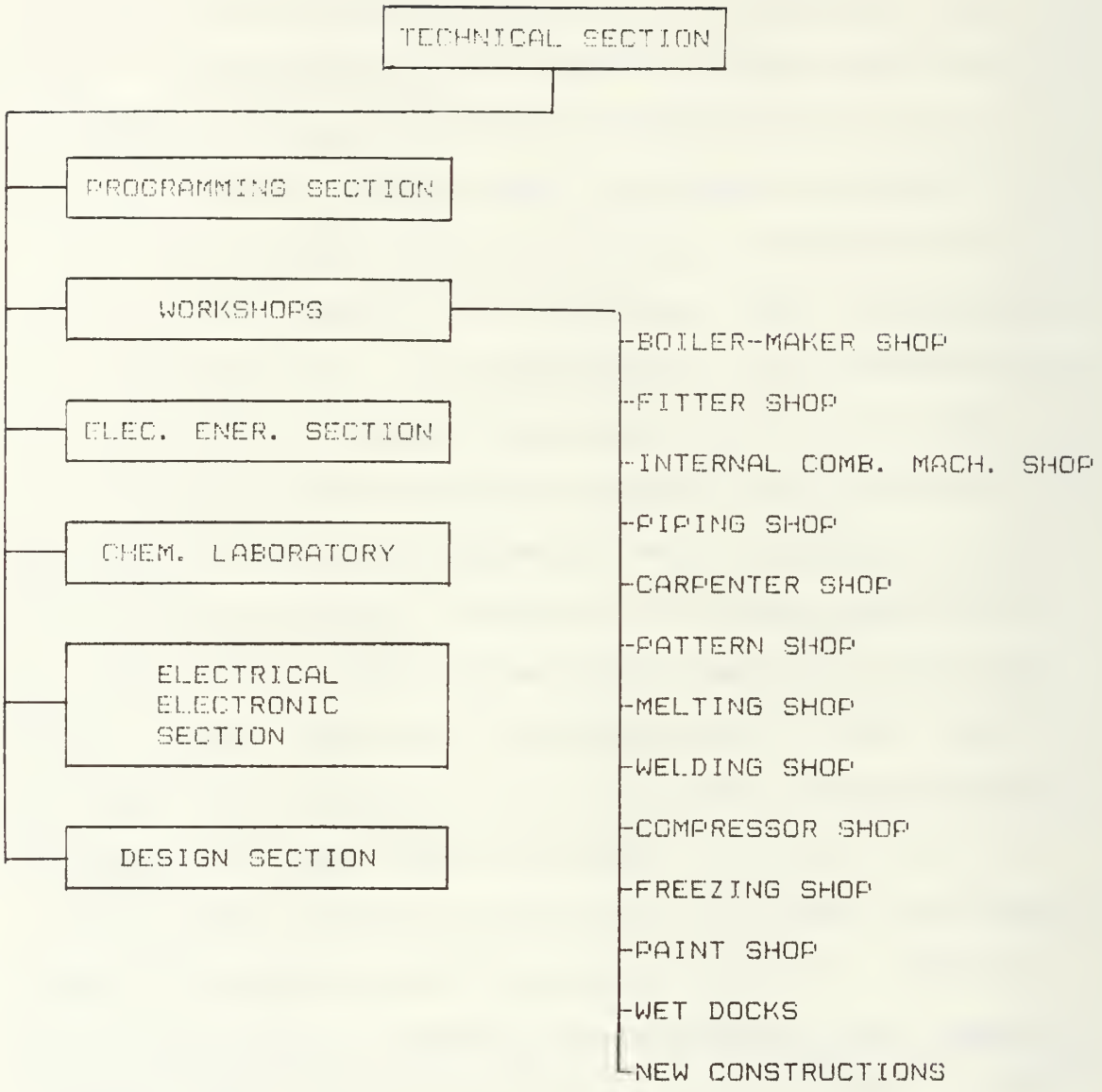

Figure 3.2 Technical Section Organization

There are two parties working simultaneously on a ship, doing different but somewhat related jobs, during the ship's repair in a naval base. The first is the naval base personnel, and the second is the ship's force.

These two parties have their own responsibilities during the ship's repair. Basically, the ship's personnel have the responsibility of conducting training in order to maintain the ship's operational readiness while fulfilling the scheduled activities of ship project network within the specified time limits without causing any delay in the activities of the naval base personnel.

On the other hand, the naval base personnel have the responsibility to accomplish the repair of the ship as effectively as possible thus supporting the operational readiness of the ship and minimizing the total repair cost.

Thus, three or four months before the start of the overhaul process the management of the ship prepares the work package and sends it to the programming section of the naval base.

Usually a pre-test and inspection is conducted jointly by the naval base personnel and the ship's force to determine the hull and machinery condition, define the repairs required and thus allowing them to prepare a menu accurate work package. Finally the naval base scheduling office, which is a subsection of the programming section, creates the project network based upon this package.

Since there is a limited amount of available resources (budget, capital, labor etc.), there are some required jobs which are not accepted by the naval base. Therefore, these jobs are undertaken by the ship's force.

Other factors that may result in conflict between the naval base and ship's project networks are the following:

1. The information flow between the ship and naval base concerning the material condition is not complete.

2. Since the naval base personnel have no access to the ship except during the pre-test and inspection period, the work package is often prepared under strict time constraints and the estimated works may not be accurate as desired with new job requirements often being added to the existing network.

3. Additionally there are some other factors such as illness of the workers or some repair material and tools which are not available when needed.

4. Funds, manpower, worker's facilities, and materials required are not determined early enough or with sufficient accuracy. Thus, the resources cannot be well developed in advance of overhaul. [Ref. 8:pp. 10-13]

B. STATEMENT OF THE PROBLEM

It is fact that there is a limited supply of a wide variety of resources: people, mechanical and electronic equipment, etc. In his natural environment man has many needs, which are satisfied by the usage of material and services that are called goods. The majority of goods however, are rather scarce and thus a fundamental problem faces the planners of each naval base as to how to allocate/use available resources so that the greatest number of the base's needs are met. If more resources are

allocated to one function, fewer resources will remain to be allocated for other services. [Ref. 5:pp. 3-4]

Success of any repair function in a naval base is based on the contribution of many productive factors (e.g. human labor, machinery, buildings, etc.). Thus, the main responsibility of personnel of the programming section in a naval base is to analyze and determine the priority and duration of each job in man-hours and to determine the workshop involved and the resources which are needed. This information is usually put in an arrow diagram form and constitutes the whole plan of work that must be done to the ships during periodic maintenance or overhaul. This plan is used by the planners who must assign the resources required each day (labor, capital and physical means). [Ref. 6:pp. 9]

The factor of labor in a naval base includes only ship's force and civilian repair personnel. When the activities are a known quantity then the factor of contribution of labor depends on the size of the labor force. The size of this labor force can vary according to the size of activities of the naval base.

Capital includes all facilities such as machinery, wet docks, floating docks, cranes, buildings, means of transportation etc. that have been produced by man and utilized in turn in the accomplishment of other services.

The physical means includes all required goods and materials. These are not necessarily fixed in quantity. [Ref. 5:pp. 17-19]

Since under normal circumstances more than one ship, in fact many ships, will be present at the same time for repairs, many projects have to be dealt with simultaneously. Even though it may appear that the repairs are independent, there are many interactions between them because of the utilization of one type of resource for one of them reduces the availability of that resource for the rest of the projects [Ref. 6:p. 9]. It is therefore, imperative that the available resources (workers, equipment etc.) be used as efficiently as possible.

Therefore, the most serious problem that the planners face in a Naval base, is the allocation of available resources (human force, mechanical equipment etc.) across individual requirements (maintenance of ships, overhaul processes etc.).

IV. MEASURING PRODUCTIVITY

This chapter considers various approaches to measuring Naval base workshop productivity. The purpose of the first two introductory sections is to present a clear understanding of the concepts behind the measures of productivity that are used for analysis of its role in the workshops of a Naval base. So in addition to total Productivity measures relating output to all inputs used in production, output may also be related separately to each major class of input. In this chapter the meaning both of total Productivity and of the spectrum of partial Productivity ratios is presented. [Ref. 9:p. 12]

The following sections present a description of a number of basic considerations in organizational measurement that should be used in analyzing productivity measurement approaches. Categories of measurement methods reviewed are efficiency measurement, and effectiveness measurement. Effectiveness and productivity may be examined from one of the following standpoints in the Organization's level.

1. Division
2. Section
3. Branch
4. Workshop

On the other hand the industrial engineers have been developing and refining the procedures used to measure work. Standard methodologies, involving both direct and synthetic measurement procedures such as time study, work sampling, standard data, predetermined time systems, and physiological measures, are the measurement tools available to the Industrial engineer. The use of modern computer technology has changed and refined the traditional measurement devices, but the procedures remain the same. [Ref. 10:p. 131]

A. GENERAL MEASUREMENT ISSUES

1. Measurement Definition and Benefits

Measurement is a process which involves assigning numbers to objects (i.e. repair machines, workshops involved), events or attributes according to specified rules or procedures. More precisely, a measurement operation is:

> a standardized rule that maps each of a set of objects into one, and only one, of a set of categories or numbers. [Ref. 11:p. 5]

The concept of standardization is critical to the measurement process and, in practice, means that different people who apply the rule to particular events and situations obtain very similar results. Thus, an organizational productivity measurement process is standardized if two different analysts assign the same values to the same organization at a given point in time.

Use of standardized organizational measurement procedures offers many benefits to both research section staff and programming section staff of a Naval base. First, numerical values provided by measurement procedures allow reporting of results in finer detail and more precisely than would be possible with subjective descriptions. These numerical indices also permit use of statistical analysis procedures. Secondly, measurement results facilitate communication between the above mentioned staffs and others who influence or are affected by the Naval base activities. [Ref. 1:pp. 31-32]

2. Levels of Measurement

The type of measurement operation selected or developed is called measurement scale and depends on the attribute to be measured and the purpose of measurement. Four levels of measurement are typically identified by statisticians: Nominal, ordinal, interval and ratio.

1. In nominal scale of measurement, numbers are used either as labels or as a means of separating workers, machines, or events into different classes or categories.

2. In ordinal scale of measurement, (1) objects of measurement are ordered from smallest to largest with respect to some attribute, (2) there is no indication of how much of the attribute the measurement object possesses, and (3) referred to measurements where only the comparisons "greater," "less," or "equal" between measurements are relevant.

3. Interval scale of measurement procedures lead to a rank ordering of objects of measurement with respect to an attribute when the distance between objects are known. For example, if the measured productivity in 1980 is selected as the arbitrary zero-point or base year, productivity in successive years is expressed in relation to the 1980 value.

4. Ratio scale of measurement includes all the characteristics of interval scale of measurement, and is used when the ratio also between two measurements is meaningful.

In developing and interpreting measures of productivity, the level of measurement produced by a particular measurement operation is significant. If a given measurement operation produces only ordinal measurement and ratio interpretations are attempted, they will lead to inaccurate conclusions. [Ref. 12:pp. 64-66]

B. THE ROLE OF MEASUREMENT IN PRODUCTIVITY IMPROVEMENT

Production in a naval base is relative to the participating productive factors. Thus, productivity can be characterized as the measuring device of each individual productive factor. We can see that Productivity is an important topic , because it can be considered as a representative indicator of the overall efficiency of the naval base. Thus, if workshops of a Naval base increase the total volume of production (work output), that may or may not represent a productivity improvement, depending on the resource inputs used in that increased production. When the planners of a naval base increase the work output of the workshops with the same or fewer of productive factors spent, then productivity is improved. Productivity improvement will occur if any of the following conditions to exist:

1. Output increases and input decreases
2. Output increases, but input remains constant

3. Output increases and input increases, but [illegible] rate

4. Output decreases and input decreases, but at a more rapid rate

The productive factors are usually measured in terms of labor hours required to produce the associated work output. However, before we reach the productivity improvement destination, we must know where we have been. Before we can be sure that our actions have increased productivity, we have to be able to measure the current productivity level. Hence, there are two fundamental aspects of productivity.

The first one is the productivity measurement and the second is the productivity approach and improvement. Productivity measurement can be viewed as an essential part of the productivity approach and improvement program for the workshops of a Naval base. However, this term can be considered as the measurement of outputs and inputs. But how can we measure outputs of the workshops? By the amount of time spent by the staff in productive effort? Ships served during a time period? This problem arises from the fact that we don't know what the output units are. If the output units are equivalent (e.g., number of overhauled machines, or tons of steel produced), they can be measured as a simple count of units produced. For example, a convenient measure of output for a worker may be the number of machines repaired. If each machine is equivalent to all others, there should be no problem. If so, the raw number of units

produced is the easiest output measure to obtain. Even, if the output units are not equivalent (as in a ship repair or overhaul facility), they cannot easily be counted, and therefore, the measurement needs are more complicated. In that case work measurement techniques are used to develop standard measures of work output.

On the other hand, the resources used in the production of output are usually called inputs. The four resources most commonly considered as important imputs are: (1) labor, (2) capital, (3) materials, and (4) energy. Of these, labor is by far the most widely used although, as work becomes more and more automated, capital and energy become more important. But, the question is how we can measure these imput resources? [Ref. 13:p. A-1]

For meaningful comparison, inputs and outputs must be on equivalent scales and the subcomponents of each must allow aggregation. This is often attempted by using some monetary systems. Since a before-and-after comparison is required to evaluate any improvement procedure, measurement is crucial to productivity improvement. [Ref. 14:pp. 685-686]

Generally, one approach to the measurement of productivity is to develop a vector of measures which can be used to guide and monitor the efforts toward improving the workshops productivity. This is very important in understanding the reason for the development of a Productivity Measurement System. One possible objective is to provide a

base for comparison of one naval base section with another. For this objective to be realized agreement must be reached among the various naval bases on the definition of productivity and the procedure for "objectively" quantifying it. Following this path a naval base division will likely resort to the use of the standard economic definition of productivity as the ratio of output to input. The particular measure developed will depend on the respective perspective of what the outputs and the inputs are for the particular naval base. Often productivity is qualified or captured with indicators like: repair/person-hour, standard dollars produced/person-hour, profit/invested dollar, etc.

Another role is that of a useful decision to the programming section of the naval base. A productivity measurement system can provide guidance to managers as to where effort should be directed to enhance the overall performance of the naval base. Once in place, the measurement system can then aid in the explicit assessment of the impact of these efforts on the performance of the workshops of a naval base. One can hope that the measurement will become a permanent part of the management information decision system. For this implementation to occur, it appears that several ingredients must exist:

1. The system must be perceived as relevant and useful to the members of the programming section team.
2. The system must coincide with management intuition with some acceptable degree of reliability.

3. The cost of the development and maintenance of the system must be commensurate with the perceived usefulness of the system as a decision aid.

4. The users of the system should have some degree of involvement with the development of the system. [Ref. 15:p. 569].

C. METHODS OF MEASUREMENT

1. Efficiency Measurement

Efficiency is the degree to which the system utilizes the "right" things. It can be represented by the following equation:

$$\frac{\text{Resources expected to be consumed}}{\text{Resources actually consumed}}$$

From this equation, we can see that efficiency is simply the comparison between resources we expected or intended to consume in accomplishing specific goals, objectives, and activities and resources actually consumed. Efficiency can be, therefore, a measure of an organizational system's performance that focuses on the input size. We can develop indexes to compare the efficiency of one period with efficiency of another period. [Ref. 16:p. 42]

Table III indicates two categories of productivity measurement methods. In the first category of efficiency measures, efficiency is defined as a ratio of outputs to inputs. Both outputs and inputs are expressed in terms of physical units (e.g., number of items, hours etc.) or in

TABLE III

PRODUCTIVITY MEASUREMENT METHODS

Efficiency Measurement	Effectiveness Measurement
1. Output/Input Measures	1. Goals Achieved
a. Form I Micro	2. Quality
b. Form I Macro	a. Process Quality Ratio
c. Form II	b. Prevention Quality
d. Form III	c. Conformance to Quality standards
e. Form IV	
2. Performance Efficiency	3. Impact (External)
a. Engineered Standards	a. Impact on Another Organization's Performance
b. Statistical Standards	b. Responsiveness to Customers/Users
c. Historical or Technical Audit Standards	c. Customer Attitudes
3. Utilization Measures	4. Impact (Internal)

term of cost (dollars). Using these dimensions, we have four types of output/input efficiency ratios which are:

1. $\frac{\text{Output in Physical Quantity}}{\text{Input in Physical Quantity}}$ (Form I)

2. $\frac{\text{Output in Price Form}}{\text{Input in physical Quantity}}$ (Form II)

3. $\frac{\text{Output in physical Quantity}}{\text{Input in Price Form}}$ (Form III)

4. $\frac{\text{Output in Price Form}}{\text{Input in Price Form}}$ (Form IV)

There are also two other efficiency measures which are the level (micro vs macro) and the type (partial vs total factor). The micro level efficiency measure is used to measure efficiency at the work group, work shop division. The macro level efficiency is used for larger organizations. The measurement type is referred to whether or not the denominator of the ratio is a single or a multiple input. The micro and macro levels of measurement have different purposes. Macro level is very useful for budgeting formulation. Even though the data for macro level measures are normally aggregated up from lower levels, the gross measures of output used are not meaningful to managers who want to analyze the sources of productivity problems in their organizations. Many of the output indicators used in productivity systems are workload measures (e.g., authorized base population served, number of active duty pay accounts

service rendered, etc.). Line managers do not know productivity levels because the output data are combined with input data at organizational levels above the workshop or division.

One of the problems that managers of the Naval base have using efficiency ratios, is that they have little control over the inputs to the process. Since the number of input hours available is fixed, the commander of a workshop can allocate these hours to tasks in different ways, so that the total labor input will be also fixed. As a result of that and when there are slack periods, the labor efficiency will be poor. In cases where the the workload is heavy the labor efficiency increases. We can conclude that the efficiency ratio measures fluctuations in workload which are outside the organization's control. [Ref. 1:pp. 37-39]

a. Physical Quantity Input and Output - Microlevel

The physical quantity measures offer many advantages for efficiency measurement because they are not affected by inflation, can be compared with data from previous periods, are easy to compute and have high acceptability. Disadvantages in a Naval base are that the index may fluctuate as a result of factors that are not controllable by the Organization. An example of this kind of measure is the following:

$$\text{Labor partial} = \frac{\text{Number of line items issued by a workshop}}{\text{Total hours worked}}$$

little control over the number of personnel assigned, as in the case of the Naval base, labor partials, are misleading.

b. Physical Quantity Input and Output - Macrolevel

These kinds of measures are reported in index terms. Table IV provides how such an index is calculated using hypothetical data. The macro measures give much information to policy makers which is useful for budgeting and planning purposes. Also, they provide indication which labor resources are efficiently in relation to those of the previous period.

c. Price Outputs and Physical Quantity Inputs

These measures present outputs in terms of dollar values and are very useful in the private sector where the most frequently used output is the sales in dollars. This kind of measure is understandable to managers and is easy to compute since most organizations maintain data. In the military environment, except for industrially funded activities, there are few situations in which sales or value added are appropriate output measures. However, when aggregated output measures are used they are relativily insensitive to changes in organizational efficiency which may be less than the fluctuations in the dollar values because of factors unrelated to organizational efficiency. Because of the need to correct for inflation and other factors, this measurement form requires considerable computation.

TABLE IV

COMPUTATION OF LABOR PARTIAL INDEX

	(a) Month 1 (base)	(b) Month 2	(c) Index (b/a)x100
1. Output (Repaired Machines)	70	100	142.85
2. Input (Hours worked by workshop Personnel)	1000	1200	120
3. Efficiency (1/2)	0.07	0.083	0.581

difficulty coupled with its low validity, reduces its acceptability to managers.

d. Physical Quantity Outputs and Price Inputs

This index can be used on Navy ships to measure the number of planned maintenance actions per dollar spent. By the term planned maintenance actions we mean all the approved by the ship's commanding officer expenditures for day-to-day purchase of repair parts, tools, etc. In that amount of dollars are excluded all expenses for shipyard repairs, purchase of fuel, personnel costs, utilities, etc. In the military environment this index is very useful.

This ratio can be characterized as flawed of providing useful information to managers about the true efficiency of the organization. The price ratios are less useful than physical quantity ratios. Even these ratios corrected for the effects of inflation and expressed in index terms, the price value is not a good basis for aggregating outputs and forming efficiency ratios unless prices are proportional to units of work (labor, energy, etc.) used to produce them. [Ref. 1:pp. 40-44]

2. Effectiveness Measurement

Effectiveness is the degree of how well the outputs achieve the desired goals or how much results are obtained because of the outputs. This measurement approach assumes that quantifiable goals have been established and performance is assessed relative to those goals and standards. In the Navy and epecially in the Workshops of a Naval base this approach is commonly used. Very close to the effectiveness is the planning process during which it is decided what goals will be accomplished, when these goals will be accomplished and finally what kinds of quality standards to adapt. However, in one way or another we determine goals, objectives, activities and work toward them. To measure effectiveness, we simply compare what we said or intended to accomplish against what we actually accomplished. Therefore, effectiveness is an output or accomplishment issue. To

evaluate the degree of effectiveness we need at least three criteria: Quality, Quantity and Timeliness. [Ref. 16:p. 40]

a. Quality

Quality is the degree to which a product or service conforms to a set of predetermined requirements and specifications related to the characteristics that determine its value in the marketplace for which it was designed. The keyelement of quality that distinguishes it from effectiveness is the concept of quality attributes. A quality attribute is a specific quality characteristic for which a product is designed, built, and tested. There are more questions related to keyquality and referred to a Naval base such as: Are the planners satisfied with the repair of a machine or the overhaul process of a ship? Will the repaired machine do what it is intended to do?

There are two primary elements in the equation of Quality. Equating quality with satisfaction, the quality of the workshop's outputs as perceived by the staff of the ships is nothing more or less than providing them with <u>accuracy</u> and <u>timeliness</u>. In other words, the quality can be expressed as:

Quality = accuracy + timeliness

Both accuracy and timeliness, in combination, are required if you are to produce quality outputs in the sense that you are generating customer satisfaction. The Quality of the outputs produced by the workshops of a Naval base is dependent upon five basic factors, as are illustrated in Figure 4.1.

Those factors are design, equipment, materials, scheduling, and performance.

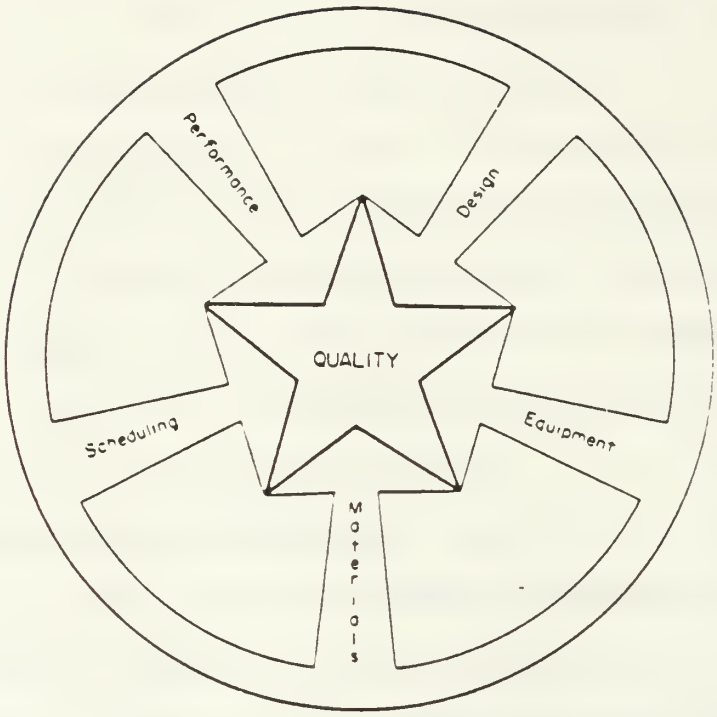

Figure 4.1 Factors of Quality of Outputs

(1) Design. The quality of outputs in a workshop of a Naval base (repaired machinery, cleaning of the fuel tanks of a ship, overaull of a steam boiler, etc.) depends not only of the outputs but also upon the design of the equipment required to produce those outputs. When planners improve the quality through the design it does not necessarily mean higher cost.For example, the design can be simplified so that the outputs can be accomplished using fewer operations.

For Naval vessels quality of design is necessary to maintain the trustworthyness of the equipment and the fighting ability of the ships.

(2) Equipment. Another important impact on quality has the ability with which the provided equipment, tools, and machinery of the workshops can accurately and reliably produce the desired outputs. The selection of the equipment and tools capable of both holding design tolerances and providing the required outputs in sufficient quantity to favorably impact costs critical to the workshop's success. If the processing equipment selected can accurately and reliably meet established design tolerances, then reasonable costs and acceptable quality can be expected. If not, we shall have high costs.

(3) Materials. Workshops use many types of material to produce their outputs. All of these materials must meet specifications and requirements. The best design coupled with superior equipment, a highly skilled work force, and a schedule providing adequate process time sometimes is incapable of overcoming the negative impact upon the quality of products caused by faulty or substandard materials. Many times substandard materials which are placed on repaired machines can result in the loss of the machine or the operator's injury.

(4) Scheduling. Scheduling can obviously affect the timeliness with which outputs are delivered and could have a tremendous impact on the overall resultant quality. Less obviously, poor scheduling can adversely affect the conformance of outputs to standard. Recognizing promised delivery dates of repaired equipment and that insufficient time is provided for proper processing, operating workshop management may, depending on the pressures applied to meeting that date, take shortcuts which result in substandard quality being shipped to the stuff of the ships.

(5) Performance. Finally, human performance has an important impact of the produced outputs. Equating performance we shall see that it is dependent upon two factors: skill and motivation.

Performance = Skill + Motivation

Also, skill is a function of the learning and experience.

Skill = Learning + Experience

On the other hand, motivation depends upon the attitude, environment, and the payoff.

Motivation = Attitude + Environment + Consequences

All the above mentioned have a significant influnce on the quality of produced outputs. [Ref. 17:pp. 114-118]

b. Quantity

The activities of the workshops, if designed correctly, create outputs that in turn can also be measured in terms of quantity, such as, the repair of a number of

machines, the overhaul process of a ship, etc. The quantity of outputs is a representative indicator of how the input resources may be or may not be productive (human labor, mechanical and electronic equipment, etc.).

c. Timeliness

If we want our measurements to serve as an effective tool, as they are intended, they must be communicated to the planners of the workshops of a Naval base, on a basis as near to real time as practical. Knowledge at every moment of how each workshop working has an effect upon how they will proceed. Whereas real time, productivity measurements may not be practical, the system would be designed to recognize and communicate, to those planners, significant exceptions or deviations from plan at least a daily basis-time not to exceed a period of eight working hours.

3. The Study of Time

The planners of the Naval base after having observed of how each workshop working, they are ready to set the related standard(s) or quantify their expectations. The standards serve as a goal against which actual performance can be measured and evaluated. Standards can be developed via statistical means based upon past performance. One of the oldest tools used by industrial engineers in work measurement is the stopwatch time study, a simple way to see how long the tasks take to complete by using a regular watch. With time study we can measure the present level of performance.

In addition to this time study can be used to estimate, to schedule production jobs, and for other planning and control purposes. Before the time study phase we must create a standard time which can be used for measuring increases in productivity. Standard time has been defined by the industrial engineers, as the time required by an average worker, who is the typical or representative worker among all the other workers, working at a normal pace, to complete a specified task using a prescribed method. The average worker will not be the best or worst worker but must be experienced in performing the job which is under investigation. Next point of difficulty in standard time is the actual work done and the method by which is completed. All tasks must have a starting and an ending point. Finally we have to keep in our minds that determining and implementing the best method is a key part of the productivity improvement process.

A "normal pace" is anything we want it to be. It is arbitrary and very few organizations use the same normal pace. There is no one normal pace that is universal to all organizations. The normal pace is a reflection of what should be performed, not what is being performed. Other people work faster than normal and other work slower. Thus, rating is the process of comparing the actual work being performed with the concept of analyst of normal pace and evaluating the observed performance quantitatively.

The analyst must be able to compare the observed activity with the predetermined standard of normal pace.

Another concept related to the study of time is the allowance or PFD (personal, fatigue, and delay) allowance. As the work day progresses, workers do become tired and are less able to perform as they did early in the shift. In that case, the standard time must be adjusted to reflect these personal, fatigue, and delay factors. Under these conditions the production line breaks down due to the worker's rest, such as the visit of a worker to the water fountain, etc. The PFD allowance is usually expressed as a percentage of the standard time and added to the time allowed to complete the particular task being studied.

The standard time is given by the following relationship which is the product of the actual observed time, the rating, and the PFD allowance.

Standard Time = (Observed Time)(Rating Factor)(1+PFD Allow.)

The first timing device for making a time study is the stopwatch. But today, there are a wide variety of tools, (Figure 4.2) ranging from electronic stopwatches to computerized timing devices that transmit the observed or directly measured times automatically to a processing unit for analysis.

It is obvious that a great number of organizations don't use standards. The reason for that is because one of the more common problems is the worker's fear. Every worker

must be convinced that the reason the time study is being conducted to set the standard time and not to judge the ability or the worker. The first step in the procedure of setting standards is the selection of the job to be studied. This selection will give the direction of how the data will be collected. During the time study the analyst should learn as much as possible about the job before performing the time study. He must also include information by talking with other engineers, technologists, and analysts who are familiar with this job. An important part is that every job must be observed under normal operating conditions. Jobs can be divided into elements for simpler analysis.

There are two methods to record the time study data. The first one is the continuous method in which the data collection involves starting the stopwatch when the study begins, and allowing it to run until the study is complete, and the second one is the snapback method in which the analyst resets the watch at the end of each element. All data about the job are collected on observation sheets which are then analyzed to derive the standard time. This standard time can be used as a base to measure increases in productivity, as a tool to develop standards for other jobs that are similar to the one being studied and as a tool for production planning. [Ref. 10:pp. 134-151]

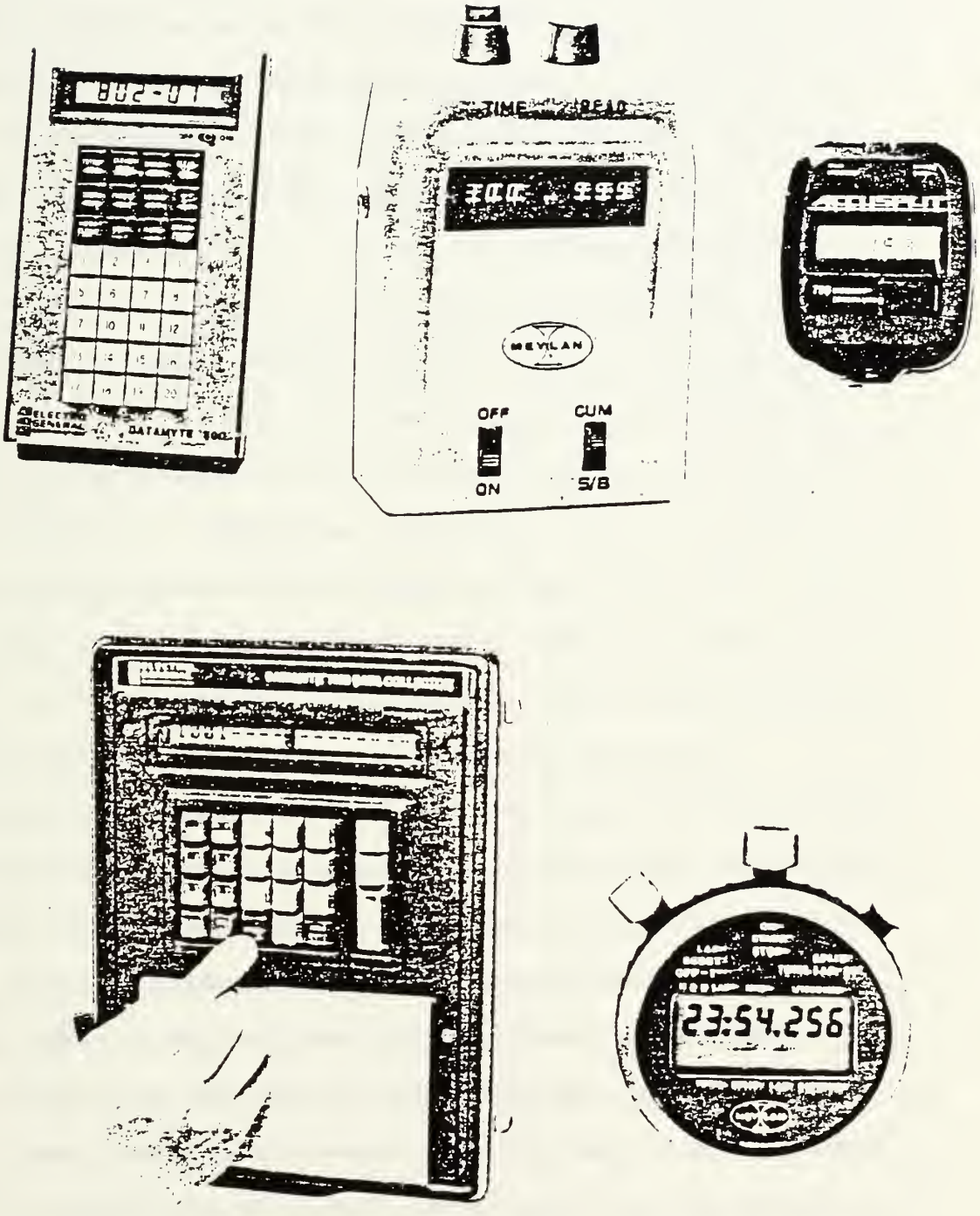

Figure 4.2 Timing Devices

4. Work Sampling

The planners of a Naval base must choose the most appropriate method to set the performance standard(s). There are a lot of jobs where time study is not the productive way to set standards. This method is more useful in setting time standards for jobs where the number of repetitions is very large. For that reason work sampling is another way of setting time standards.

> Work sampling, or activity analysis, is the process of making sufficient random observations of an operator's activities in order to determine the relative amount of time the operator spends on the various activities associated with the jobs. [Ref. 10:pp. 270-271]

The main goal of work sampling is to determine how long, or how many of the work hours are spent on specific types of work. Work sampling may identify that many operators spend a large portion of their work time on other activities that are not included in their duties.

If we are looking more closely to the definition of work sampling we shall see that it needs some explanations. One of the most important things in statistical theory is the term of sufficiency, or the concept that the larger the sample size, the more accurate, the results will be. Much of our knowledge concerning the world we live in is the result of samples. Quite often the conclusion we draw from the samples are not accurate. However, in most cases, the conclusions are more accurate than if no samples had been observed. Our process of forming conclusions may be placed

within the framework of an investigation. To investigate the quality of a workshop we have to observe each worker to obtain information about the population of all workers. Usually, this is impossible or impractical, so only a sample from that population is observed. [Ref. 12:pp. 61]

The sample must be representative of the population and may consist of those elements that are easily accessible to the observer. In addition to making sure the sample is representative, it is just as important that the sample be taken at random times throughout the work day. The randomness of a sample give us better results. By the term random we mean that each of the possible samples was equally likely to be observed. Often an investigator already knows that there will be an effect; what he wants to do is to estimate its magnitude and calculate an interval within which the true value almost certainly lies. Such an interval is called confidence interval. Common confidence levels are .10, .05, and .01 which means, based on our analysis of the worker's activities, we believe that our results will be accurate 90, 95, or 99 times out of 100. [Ref. 18:p. 107]

If an operator spends less time performing a particular task, the analyst must take more observations to ensure that the task is measured properly relative to its use of the operator's time. Table V indicates the required number of observations which must be taken for 95 percent confidence based on accuracy, confidence, and the expected time

spent on the job. The variable p represents the preliminary estimate of the percentage of time spent performing a particular activity and the 1%, 5%, 10% are the levels of accuracy that are used when estimating the percentage of time spent on particular activities.

During the work sampling study the analyst must have some guidelines as for example to establish the objective of the study, to identify the people performing the task, to establish the time period during which the study will be conducted, and, finally to define the activities that are performed by the people under study. When the analyst all the necessary elements for his study he has to summarize them by calculating the percentage of time actually spent on every particular task. If a standard is to be set, this percentage is compared with the output for the time of study and the time per unit of output is calculated.

5. Systems of Standard Data

There are many jobs where we cannot set standards by the time study procedure, and the reason is because there are not available enough time study time analysts. In that case it is desirable to have a standard available system for each job. In the workshops of a Naval base there are a number of different outputs, many of these produced in similar ways.

TABLE V

SAMPLE SIZES FOR 95 PERCENT CONFIDENCE

P	1%	5%	10%
1	3,803,180	152,127	38,032
2	1,882,380	75,295	18,824
3	1,242,120	49,684	12,421
4	921,984	36,879	9,220
5	729,904	29,196	7,299
6	601,851	24,074	6,019
7	510,384	20,415	5,104
8	441,784	17,671	4,418
9	388,428	15,537	3,884
10	345,744	13,830	3,457
15	217,691	8,708	2,177
20	153,664	6,147	1,537
25	115,248	4,610	1,152
30	89,637	3,585	896
35	71,344	2,854	713
40	57,624	2,305	576
45	46,953	1,878	470
50	38,416	1,537	384
55	31,431	1,257	414
60	25,611	1,024	256
65	20,685	827	207
70	16,464	659	165
75	12,805	512	128
80	9,604	384	96
85	6,779	271	68
90	4,268	171	43
95	2,022	81	20
99	388	16	4

The manufacturing or repairing processes have characteristics that occur no matter what the shape of the product is. Machine tools can make metal works at certain rates in certain materials regardless of the end use of product. The time required depends upon certain identifiable variables such as length and depth of cut, machine speed, and so on.

The analysts develop the set of time standards which provides the data base necessary for a standard data system.

The methodology used to develop standard data systems can be summarized as follows:

1. The first thing is to develop a data base. Once the data are collected then must summarized. Elements that describe similar operations must be identified. These elements will be used to determine any relationship. The elements must be divided in variables which depend upon certain characteristics. As characteristics change, the time for completing operation will change.

2. Next step is calculating the average base time which is the sum of the average time allowed for constant elements.

3. After developing the standard data system we must plot the data and see how well the standard data relationship fits to the existing data.

To be more understandable the above mentioned procedures of how the Data System is constructed I am giving the following example for the boiler-maker section which repair the boilers of the destroyers by forming the tubes in the appropriate shape which vary in the inside and the outside diameter. The given hours for forming 500 tubes are not taken from real conditions but author wants to explain how the procedure works. Table VI shows the characteristics for the various types of tubes formed by the boiler-maker section as well the direct observation stopwatch time study values for the time required to form 500 tubes for each type of them. For the A, B, C, D types the thickness of metal is 1/16" and for the E, F, G types the thickness of metal is 1/8".

TABLE VI

TIME STUDY DATA FOR BOILER-MAKER SECTION'S DATA BASE

Type	Ins. Diameter	Out. Diameter	Hours/500
A	0.500	0.5625	0.92
B	0.625	0.6875	1.13
C	0.750	0.8125	1.53
D	0.875	0.9375	1.98
E	1.000	1.125	2.16
F	1.500	1.625	2.34
G	2.000	2.125	2.58

Since two variables are involved it is impractical, to plot the time as a function of each variable separately. Figure 4.3 shows time plotted versus the inside diameter and Figure 4.4 shows time plotted versus the outside diameter of all types of tubes. An examination of these two graphs reveals that the boiler-maker section needs more time to form the tubes as the inside and outside diameter increases. It is appropriate to say that time is a function of the inside and the outside diameter. Sometimes products have many elements in common, as for example in the case of tubes, the thickness or the inside diameter. In that case standards set must be more productive than the standard data.

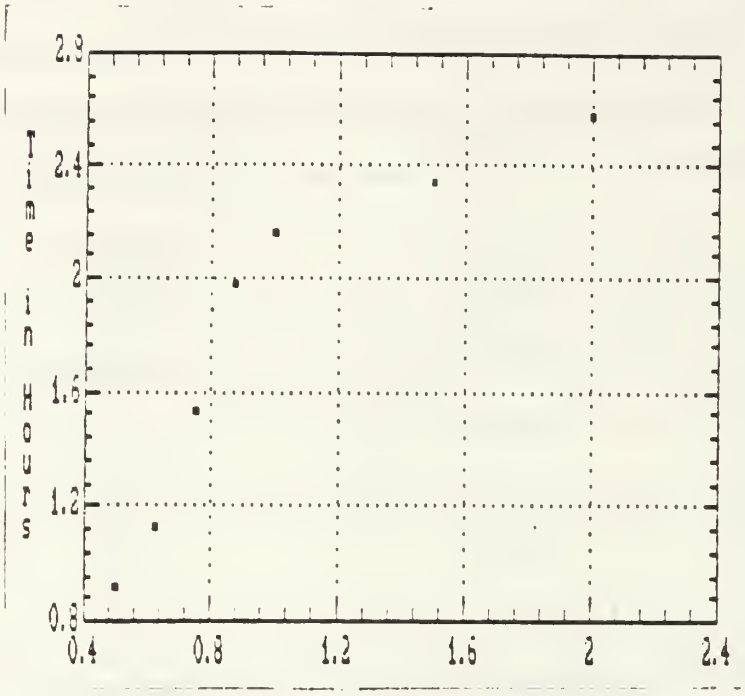

Figure 4.3 Time vs Inside Diameter

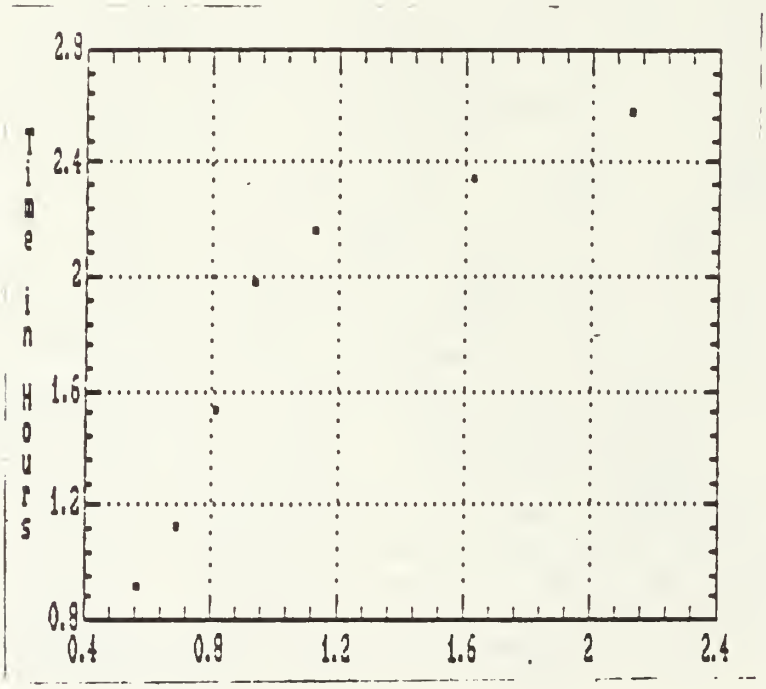

Figure 4.4 Time vs Outside Diameter

6. Predetermined Time Systems

Another way to set time standards without using stop watch time study is the use of the predetermined time standards which are designed for a wide variety of applications. These systems are also designed with the specific objectives of ascertaining labor costs and ways to reduce them. This is done by finding the best way to do the work, and determining the normal time required to perform the task. The procedure to set time standards by using the Predetermined time systems is about the same. One of the major advantages is that the workshops may not have developed their own data bases. Generally, predetermined time systems, such as Methods Time Measurement (MTM), Basic Motion Timestudy (BMT), Work Factor (WF), or the hypothetical Always Fair Times (AFTWAYS) are presented as systems that can be used to set time standards for workers working at a normal pace. [Ref. 10:pp. 228-230]

7. Physiological Measures

All these measurement procedures which are examined so far, have evaluated the productivity of workers based on the time required to complete a specific job. Another way to measure the work of the individual worker, is to measure the physical energy expended performing a specific task. In that case we can measure total oxygen consumption, and variations in body temparature and heart rate.

Newest methods have shown that these measurements are strongly related with performed work. The objective of these

Purpose : To estimate the physiological characteristics when the worker is doing a task. Certain parameters or these characteristics change as the person performs a task. To maintain worker efficiency, it becomes necessary to maintain physiological indices as close to expected normal levels as possible by allowing for sufficient rest and recovery time.

V. PRESENTATION OF THE MODEL

A. COMMENTS ON THE AMERICAN PRODUCTIVITY CENTER (APC) MODEL

As mentioned in Chapter IV there are a wide variety of approaches to measure the productivity of an organization. These productivity measurement and calculation methods on the organization's level are either extrapolated methods which are used to determine productivity indexes or rules-of-thumb developed within the organization. The most traditional productivity measurement models are a "partial measure" only, or in other words, they refer to the fact that labor is the only reference to which output is indexed. For that reason the American Productivity Center (APC) has undertaken the task of developing a total productivity measurement model which includes all the inputs which take place during production, such as capital, energy, and materials, as well as labor. In the workshops of a Naval base by considering all inputs we can compare the relationships of increasing/decreasing the different inputs and productivity, for example, the replacing of the input labor with an investment in new machinery or electronic equipment.

The APC productivity measurement model is a powerful tool in the hands of the managers and can be adapted to any organization. The model provides indices which relate performances between two operating periods. The indexes which

are taking place in productivity analysis refer to ratios between outputs and inputs in the current period, and to ratios in an initial or base period. American Productivity Center measurement model uses three indices which are:

1. The Productivity Index
2. The Pricing Recovery Index
3. The Cost Effectiveness Index

All the results of the model must be placed under analysis of variance when considering the money contribution of the resources used. [Ref. 19:p. 41]

B. THE PRODUCTIVITY INDEX

In the American productivity Model, the productivity index relates performance between two periods, or relates output to input ratios in a current period to output to input ratios in an initial or base period. The productivity index uses a base period weighting, or Laspeyres, and the referred quantity ratios used are price-weighted ratios rather than physical ratios. This relationship is shown in equation 1.

$$\text{Productivity Index} = \frac{\dfrac{\text{Current Output Quantities}}{\text{Base Output Quantities}}}{\dfrac{\text{Current Input Quantities}}{\text{Base Input Quantities}}} \qquad (1)$$

Mathematically, equation (1) can be represented as equation (2).

$$\text{Productivity Index} = P = \frac{\dfrac{Q_2^{\,0} P_1^{\,0}}{Q_1^{\,0} P_1^{\,0}}}{\dfrac{Q_2^{\,1} P_1^{\,1}}{Q_1^{\,1} P_1^{\,1}}} = \frac{QI^0}{QI^1} \qquad (2)$$

where: Q_1^o = Output quantity in base period

Q_2^o = Output quantity in current period

Q_1^I = Input quantity in base period

Q_2^I = Input quantity in current period

P_1^o = Output price in base period

P_1^I = Input price in base period

QI^o = Laspeyres output quantity index

QI^I = Laspeyres input quantity index

P = Productivity index (Period 2 to period 1) [Ref. 20:p. 195]

C. THE PRICING RECOVERY INDEX

As the productivity index the pricing recovery index reflects changes in pricing recovery over two periods. The pricing recovery index uses a current period weighting, or Paasche, and shows to what extent the organization has been able to absorb the increases in prices of inputs and therefore been able to combat inflation. This relationship is given by equation 3.

$$\text{Pricing Recovery Index} = \frac{\dfrac{\text{Current Output Price}}{\text{Base Output Price}}}{\dfrac{\text{Current Input Price}}{\text{Base Input Price}}} \qquad (3)$$

Mathematically, equation (3) can be represented as equation (4).

$$\text{Pricing Recovery Index} = R = \frac{\frac{Q_2^U P_2^U}{Q_2^U P_1^U}}{\frac{Q_2^I P_2^I}{Q_2^I P_1^I}} = \frac{PI^U}{PI^I} \qquad (4)$$

where: P_1^U = Output price in base period

P_2^U = Output price in current period

P_1^I = Input price in base period

P_2^I = Input price in current period

Q_2^U = Output quantity in current period

Q_2^I = Input quantity in current period

PI^U = Paasche Output price index

PI^I = Paasche Input price index

R = Pricing recovery index (period 2 to period 1).

[Ref. 20:p. 197]

D. THE COST EFFECTIVENESS INDEX

The cost effectiveness index relates value ratios of outputs to value ratios of inputs for the two periods under consideration. This index reflects how costs for the current period compare with a cost relation-ship established for the base period which can be seen as the ideal costs. In other words, this index is given by equation (5).

$$\text{Cost Effectiveness Index} = \frac{\frac{\text{Current Output Value}}{\text{Base Output Value}}}{\frac{\text{Current Input Value}}{\text{Base Input Value}}} \qquad (5)$$

The mathematical expression of equation (5) is given by equation (6).

$$\text{Cost Effectiveness Index} = E = \frac{\frac{Q_2^{U} P_2^{U}}{Q_1^{I} P_1^{I}}}{\frac{Q_2^{I} P_2^{I}}{Q_1^{I} P_1^{I}}} = \frac{VI^{U}}{VI^{I}} \qquad (6)$$

where : P_1^I = Input price in base period

P_2^I = Input price in current period

P_2^U = Output price in current period

Q_1^I = Input quantity in base period

Q_2^I = Input quantity in current period

Q_2^U = Output quantity in current period

VI^U = Output value index

VI^I = Input value index

E = Cost Effectiveness index (Period 2 to period 1)

This index also, can be represented as the product of productivity index and Pricing Recovery Index as in equation (7)

$$E = P \times R \qquad (7)$$

and, shows the rate of change in costs relative to sales. The interpretation of equation (7), is that, if sales revenues increase at a greater rate than costs the index will increase, and if the sales revenues decrease in a slower rate than the cost, increase, or remain constant, the index will decrease. The setting value of these three indexes is the unity. If the productivity shows an increase over the base period the respective index will have a value greater than one, and if shows an decrease the index value will be smaller than one. If it remains constant the index will be equal to one. [Ref. 20:p. 197]

2. ANALYSIS OF VARIANCE

In addition to the calculation of the indices the American Productivity Center measurement model provides also a variance analysis. Generally, the productivity variance is the difference between the change in quantity of the product and the change in quantity of the resources used. This analysis is very important when considering the nominal value of individual resources used. Then the performance of each element used, in relationship to profitability is expressed in money.

The model provides three types of variances. The first of them is the productivity variance which is the difference between the change in the quantity of the product and the change in the quantity of the resources used. This is a representative indicator which shows the attempt of the managers of workshops in a Naval base to attain the setting goals. This kind of variances is defined in equation (7).

$$\text{Productivity variance} = C_i = V_i^I (QI^U - QI^I) \quad (7)$$

where: VI^U = Output value index

VI^I = Input value index

V_i^I = Value of an input during the base period

C_i = Cost effectiveness variance [Ref. 20:p. 198]

The second type of variance is the Pricing Recovery variance which is the difference between the change in the price of the product and the change in the price of the resources used. In other words this information shows of how

well one organization combats against the inflation. The pricing recovery variance is defined in equation (8).

$$\text{Pricing Recovery Variance} = C_2 = V_1^I (VI^U - VI^I) - V_1^I (QI^U - QI^I) \quad (8)$$

[Ref. 20:p. 198]

The third variance is the cost effectiveness variance which is the difference between the change in value of the products and the change in the value of the resources used. This variance indicates of how well each resource used contributes to the attainment of the overall goals of the organization. This variance defined in equation (9) as,

$$\text{Cost Effectiveness} = C_3 = V_1^I (VI^U - VI^I) = V_1^I \frac{V_2^U}{V_1^U} - V_2^I \quad (9)$$

where: VI^U = Output value index

VI^I = Input value index

V_1^I = Value of an input during the base period

C_1 = Cost effectiveness variance [Ref. 20:p. 198]

The pricing recovery variance also, can be calculated as the difference between the Cost Effectiveness Variance and the Productivity variance or,

$$\text{Pricing Recovery Variance} = C_3 - C_1$$

VI. REQUIRED FACTORS FOR THE APC MODEL

The American Productivity Center measurement model can be used as a basis to build a model for the workshops of a Naval Base using the following measurement guide:

1. We must identify the goals and objectives of the workshops.
2. We must determine the available elements of inputs.
3. We must define the outputs to be.
4. Finally, we must formate the model.

A. OBJECTIVES OF THE WORKSHOPS

In this section we have to determine accurately, what is the workshops of a Naval base expected to do, what are the main objectives that the workshop must accomplish, in order to reach its goals, and what are the rest of the objectives and how these are related to the main ones.

1. Workshop's Maintenance Goal

One of the primary goals of the workshop is to provide maintenance support to the fleet's ships, in such a way to maximize the ship's readiness and availability with respect to budget and time constraints. By the term ship readiness we mean the ability for all systems (machinery, electronic equipment, etc.) that support the mission of a ship must be fully operational. In other words the ship readiness is the probability that the system is either

operating satisfactorily is need to be placed in operation on demand. On the other hand, ship availability is the probability that every ship of the fleet will operate satisfactorily at any given time. The availability of a ship can be expressed as the ratio between the M.T.B.M. (Mean Time Between Maintenance) over the sum of the M.T.B.F. (Mean Time Between Failure) and the M.D.T. (Mean Down Time) or,

$$A = \frac{M.T.B.M.}{M.T.B.F. + M.D.T.}$$

2. Main Objectives of Workshops

There are two main objectives of workshops in order to maximize the ship's readiness and availability. The first one is the maintenance effectiveness which is the variable that influences ship's reliability and readiness, and the second one is the number of ship's inspections concerning machinery, electronic equipment etc. in a given period of time. To reach a high degree of availability a workshop has to attempt to increase the mean Time Between Maintenance and decrease the Mean Down Time. The M.T.B.M. is affected by the preventive maintenance which has standard intervals of time depending upon the different types of inspections of the ships.

The ship's readiness depends upon the ship's reliability. Ship reliability (R) is the probability that every subsystem of the ship will perform intended function for prescribed time under the stipulated conditions.

The reliability is expressed as a function of the failure rate (λ).

$$R(t) = e^{-\lambda t}$$

where: $R(t)$ = Ship reliability

λ = Rate of failure

t = Time

The rate of failure (λ) can be defined as:

$$\lambda = \frac{1}{M.T.B.F.}$$

In order to reach a workshop the M.T.B.M. in high levels for the most subsystems of the ships is required to keep the rate of failure in low level. But, the rate of failure depends upon the quality and of how the systems of the ships are new or not.

3. Other Workshop's Objectives

In addition to the main objectives of the workshops we have also the following:

1. Personnel require continuous training in order to maintain a high performance level.
2. The safety systems must be kept in high standards.
3. The quality of the end product must be continuously improved.
4. Each workshop must improve the utilization of manpower and material.
5. New methods must be investigated to make the planning and scheduling of maintenace work better.

B. DETERMINATION OF AVAILABLE INPUTS

The total productivity model must include all the necessary inputs and outputs of a particular process. This process can have any number of inputs. Figure 6.1 shows a diagram of a possible number of inputs which are considered in a productivity model. Both inputs and outputs must be measured in the same units so that the ratio of these to be meaningful. In the following sections provide an examination and discussion of the major inputs.

1. Labor

By the term labor we don't mean only the workers of a workshop but also the engineers and planners, namely the whole work force. In order to measure the total productivity, the total labor force must be considered. Therefore, it is better to use man-hours as the labor-input component. There are two types of man-hours to be considered, the "regular man-hours" and the "overtime man-hours". The first one is analyzed into the following:

1. Pay card man-hours according to which the employees receive their regular salary.
2. Assigned machine time man-hours which are the number of man-hours that a particular employee is assigned to operate a specified machine.
3. Actual machine time man-hours, or, the man-hours actually spent operating the machine to which assigned.

site management to be paid at the overtime rate to keep workload within acceptable limits.

Independently of the above determination the man-hours can be divided into two categories, the hours paid for and the worked hours. The first category includes all hours worked by the workers plus the not worked hours but paid for such as vacations, sick leave, etc. The second category includes all hours at scheduled work, rest periods, lunch breaks, etc., namely covers the whole scheduled work time in which the worker is working or not.

The preferred labor input in workshops is the worked hours which reflect in some way all changes in vacation practices. The records of professionals, executives, and other employees do not reflect overtime or temporaty absences from their offices, although some estimates must be made. [Ref. 22:p. 198]

2. Capital

Capital is one of the most important inputs but also difficult to measure. When we are referred to the business capital can be considered to the holding of a company, both tangible and intangible. For the accounting area capital is divided into two categories the fixed and the working capital. By the term fixed we mean all these elements such as buildings, machinery and electronic equipment, tools, etc.

[illegible] capital includes the amount of money [illegible] support inventory, cash, accounts receivable, etc. [Ref. [illegible] p. 421]

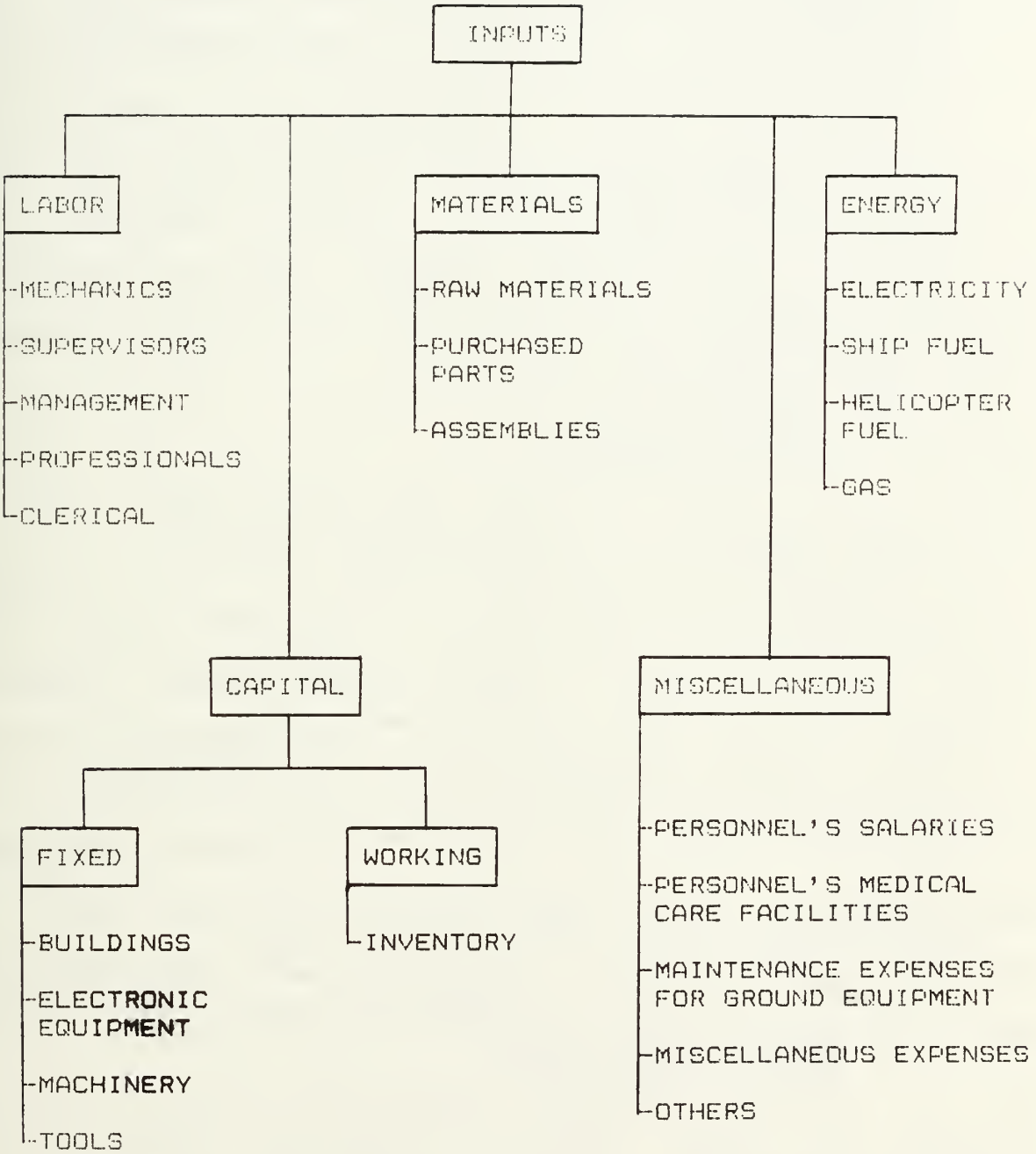

Figure 6.1 Considered Input Elements for the APC Model

3. Materials

One of the easiest inputs to the manufacturing process is the annual computation of the expenses on materials. The types of materials used depends upon the considered industry. Especially in workshops the term includes all the expenditures in sheet of metals, oil, grease, pipes of different sizes. The ship's maintenance also requires special parts in machinery and electronic equipment, whole machinery such as pumps, boilers, electronic devices which are purchased from suppliers and covered under a warranty in a specific period of time.

4. Energy Resources

In today's economy, the energy cost is one of the largest expenses of an organization's operation. In the total productivity model the total energy cost consists of all costs depending on the different energy sources. Especially for the workshops of a Naval base the energy can be divided into two areas: the electrical cost for the lighting of the workshops, or for electric drive machines and other powered equipment. Fuel refers to the operating cost of the ships during check trips, vehicles and trucks, and other ground equipment for example to generate the heat for the buildings.

5. Miscellaneous Inputs

Another big category of the inputs is the miscellaneous expenses category including all costs which arise

from the nature of these workshops. Some typical examples from that category are referred to the facilities, equipment maintenance, to the damage of some parts of the property, to the charges for telephones and teletypes, to the office supplies, etc.

C. DETERMINATION OF OUTPUTS

The outputs must be considered very carefully just as the measurement of the inputs. Since there is a wide variety of outputs the first thing that we have to do is to determine what the outputs of our organization are. Figure 6.2 shows some of typical outputs in a manufacturing organization [Ref. 21:p. 50] Especially, in the workshops of a naval base the outputs must be the provided services to the fleet ships. These services are required to maintain wartime capability of the ships in high level and are performed according to the manufacturer's maintenance plans. These plans give directions for many inspections in such a way that all systems of the ships under and over the sea level be maintained in good condition.

Some of the various services that are provided from the workshop facilities are from the simple phase checks of the hull of ships by raising them onto the wet docks, up to the heavy ones which require some replacements of the inner and outer metal surfaces, boiler's tubes and furnices inspections, measurements on the main turbines and other

delivery, checks on the piping, on the electrical and electronic equipment, etc. All these jobs are doing in regular periods of time and according to the existing specifications and standards.

To put all the above information into profuctivity model the first thing that we have to do is to convert all these functions into money. This task is extremely hard because the value of materials used, changes day by day. For example, in the procedure of performing the repair of a particular device the total cost consists from the cost of the mechanic's labor plus the cost of the new parts and materials which are required during the repair. Statistically the great percentage of the outputs consists from the above mentioned components, namely, labor and material.

D. SUMMARY

Summarizing the components described in section B for a Navy workshop facility such as Labor, Material, Capital, Energy, Miscellaneous, are the basic inputs which must be measured and be used in productivity measurement computations. Our attempt should be the inclusion of all possible inputs which are going into the workshop facility process. Since it is very difficult to consider all inputs from the major ones to minor ones, any deletion that have been made must be no substantive in the computations.

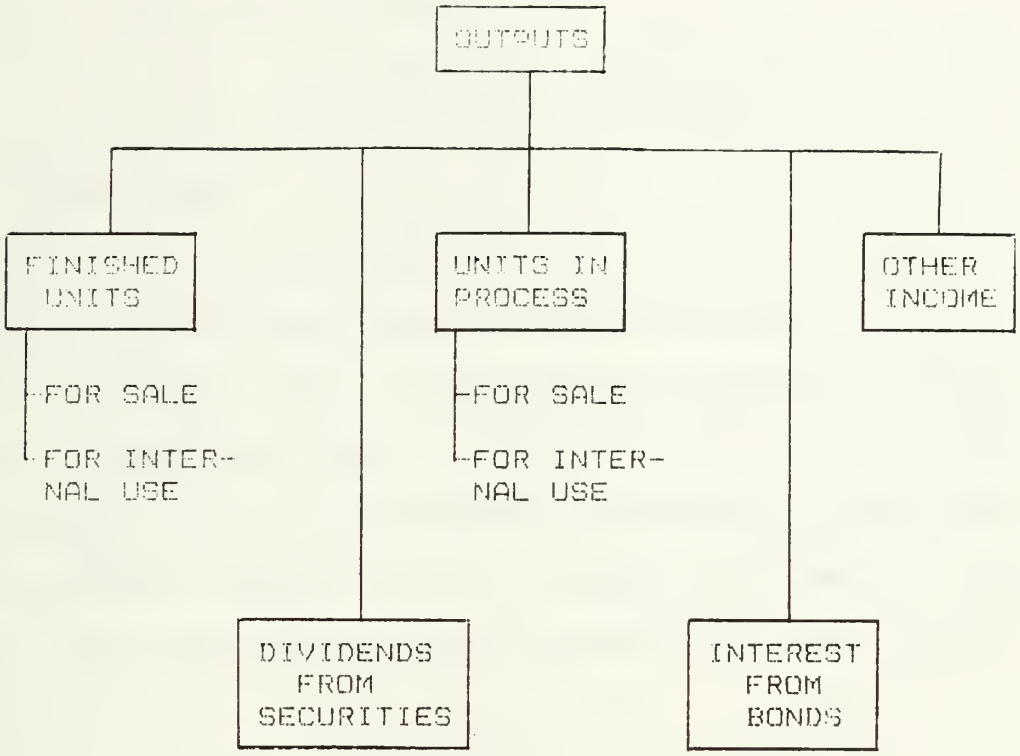

Figure 6.2 General Considered Output Elements for a Productivity Measurement Model

On the other hand the outputs as have been mentioned in section C, are composed from two different elements, labor and material. The first element consists from the tasks of the whole work power of the workshop facility as mechanics, supervisors, planners, and other personnel. The goal for measuring productivity is to measure each task and converting them into man-hours equivalent. Also assigning to each of these tasks a dollar value we shall have the total labor cost.

The second element is related to the contribution of material to the maintenance task. This element can be

It is clear that two other subcomponents: equivalent materials and purchased maintenance. The first one was derived by obtaining one average from the various contract jobs performed at the facility, and the second one is referred to certain tasks which are contracted out by the facility. The combination of these two elements provides the workshop maintenance facility's output. The final product of the facility is a repaired ship ready for trip. Certainly, there are also hundreds of other tasks to be accomplished in order to be a ship ready for trip. Figure 6.3 shows the outputs of a Navy workshop maintenance facility. [Ref. 21:p. 60]

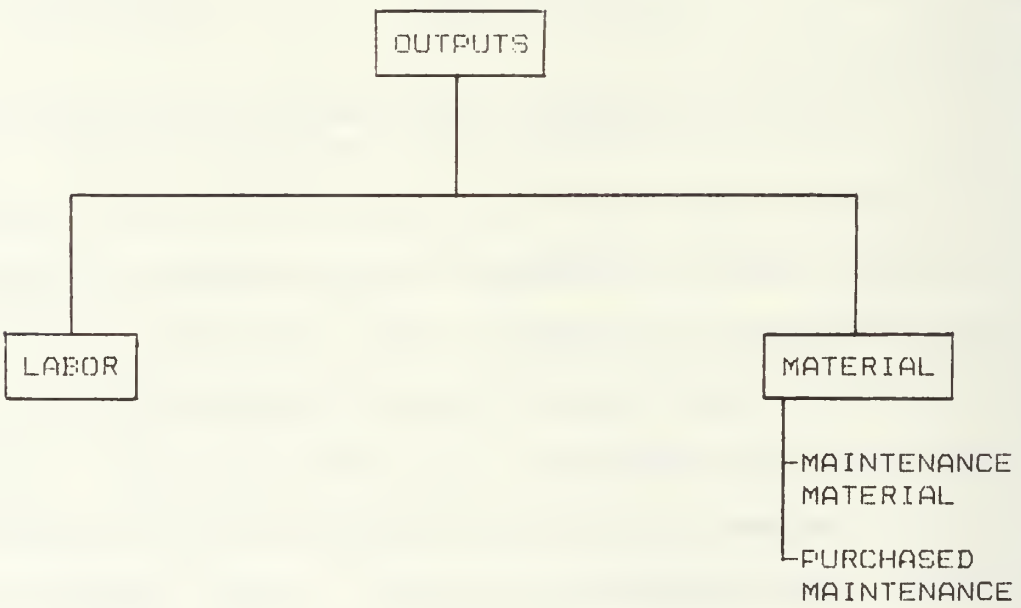

Figure 6.3 Considered Output Elements for the APC Model

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

As stated in Chapter I, the purpose of this thesis was to clarify the meaning of Productivity in a military environment such as a Naval base, to present the most applicable productivity measurement methods, and to develop a general measurement model which could be easily adapted to the purposes of the workshops. Chapters II, through V focused on the above mentioned objectives. This chapter summarizes step by step the major conclusions from the preceding chapters as some alternative methods for increasing productivity in the workshops of a Naval base.

1. Productivity measurement programs of the workshops which incorporate the concepts of efficiency may lead to the conclusion that improvements are being made when efficiency improvements are being made at the expense of effectiveness. On the other side, if these programs incorporate only the concept of effectiveness, they may fail to consider costs for achieving the levels of effectiveness and may contribute to inefficient use of resources.

2. The workshop productivity measurement model should include multiple measures of efficiency and effectiveness to assure that these facets are both adequately covered.

The following categories must be considered in the productivity measures.

a. Efficiency as the ratio of output expressed in physical units per inputs expressed in constant dollars.

b. Quality of Performance as the number of errors, number of rejected items, etc., compared to standards, budgets or goals.

c. Timeliness in terms of processing time compared to the standard time.

d. Performance Impact of the workshop staff, as the availability of all necessary equipment, safety during the worker performance, training quality, etc.

3. Efficiency and effectiveness measures are most useful if they have as many as possible of the following characteristics and features.

a. The measures must be complete. Namely, they must cover all facets of the workshop's mission.

b. They must also be comparable during different time periods.

c. The outputs used in the efficiency measures must cover the inputs used by the workshop. For example, if one of the primary imputs is labor, the output measures should cover the obtained results from all worker output.

d. The measures also must be compatible with the existing data sources rather than require the collection of new data.

e. All measures must be acceptable from all members of the workshops whose work output is being measured.

4. There are also some other characteristics which must be contained in a set of productivity measures, such as the validity of the measures, the understandability between the

members of the workshops (those who are using the data), the managers who will use the data, and the reliability of the sources of data. [Ref. 1:pp. 76-80]

B. APPLICATION IN WORKSHOP MAINTENANCE FACILITY

Before initiating a plan to improve productivity in workshops, the following basic steps must be recommended.

- We must determine the workshop goals and objectives.
- We have to identify the components that have to be included (inputs, outputs).
- We have to select the units to measure these elements that will simplify the model application with respect to available data.
- We have to fromulate the model by representing the productivity relationships.
- Last, we must provide an analysis of the model's output and interpret the results.

By measuring productivity our objective is primarily one of improving productivity. Any productivity measurement model is a decision support tool. It will identify shortcomings, but doesn't show how to correct them. A successful productivity measurement model facilitates the analysis and draws our attention toward the corrective actions that have to be done.

Top management support toward system improvement by commitment to long term goals, based on research and development programs, will increase productivity. The management of workshops have control over any productivity improvement program, and must be realized that any investment either in

personnel education, training of mechanical and other equipment will have its productive results. An, indicative variance by the model will be the key for future improvements.

By keeping close to productivity and cost effectiveness index changes, from period to period, the model enables the workshop facility to study these changes and focus management resources on successful action. From these inputs,certain conclusions can be drawn about the workshop's process cost effectiveness and can suggest direction and action management must take for productivity improvement which point out the ways of investigation for the management.

Increase in labor costs may also cause deterioration in the productivity index and/or cost effectiveness index due to an increase of workers needed per ship overhall and/or rising of wages. Organizational management must be concerned in labor productivity improvement in order to offset wage-rate increases.

An increase in capital costs can result in deterioration of productivty. Such increases are justifiable only if they are offset by an increase in production efficiency, resulting in output expansion. All capital requirements will be reduced if we decrease inventory or if we increase the utilization capacity. In order to maintain the workshop cost effectiveness level, the price of capital depending on the

cost.

We shall notice an increasing in material costs if the management makes poor control over the spare parts and supplies consuption. We can say that materials used constitute one of the greatest bad things of productivity index deterioration. On the other hand, if we increase the materials purchased prices we shall have a deterioration in cost effectiveness index if there is no parallel increase in the systems replacement cost.

Finally, if the energy consumption is unreasonable we shall have an increase of productivity and cost effectiveness indexes. This can be offset by an increase in energy prices. For that reason one of the primary concern of the workshop's management is the orientation to other alternative sources. [Ref. 19:pp. 56-59]

Independent of the above ways there are many other ways for improving worker productivity. The most well known among these methods, which have been developed and implemented with some degree of success, will be discussed.

1. More specifically, job design is based on the principle of designing the job to fit the person. Ergonomics or human factors, is an approach, which emphasizes the physical work design that should lead to increased productivity. But before we proceed to the design and improvement there are many questions which must be answered. For example how much

must be performed by him, how can we organize these functions into tasks, what equipment is required, how we shall protect the operator from the working environment, etc. According to the ergonomics concept there are three components to the most of the jobs.

a. First, is the worker productivity which can be divided into actual work efficiency (ratio of output to input) and into physiological efficiency (measure of the physical work required to complete a task).

b. Second, is the safety of the workers. Human factors try to improve safety work regulations because doing so will improve the current productivity.

c. Third, is the worker comfort. It is unquestionable that workers tend to be able to produce more when they are working in comfort.

In addition to the above mentioned components there are others which help to improve worker Productivity. Some of them are physiological measurements, the correct design of the workplace including the design of tools, equipment, the improvement of the working environment by providing adequate illumination, controlling the noise, the temperature, the humidity, etc.

2. Another good motivator to increase worker productivity is the incentive of money. As we have defined earlier <u>standard time</u> is the required time that the typical worker, working under normal conditions, has to complete a specific task. The worker who can complete this specific task in less time

most often is more productive than the typical worker. If this occurs it is also logical for management of workshops to be willing to reward the more productive workers with more than typical wages. In such a way we shall have some increase in productivity because of the effort of every worker to be more productive.

There is also another new concept in the productivity improvement process. The quality of work life according to which the workshop's attempts at improving productivity is to allow workers a more enjoyable work environment.

4. A special type of a quality work life program is the quality control circle which can be defined as a group of workers who meet for a period time every fifteen days or every month to discuss their problems and find solutions to them. These meetings aim to effect improvements in product quality, productivity, motivation of the workforce. They also give workers the opportunity to influence decisions about their work, management - employee relations and they promote training in problem solving.

5. Another concept closely related to the quality of work life programs is flexitime which allows workers to set their own hours. In that case a minimum of working hours is required for every week or month. This system gives workers more freedom and autonomy about when they work.

6. Job rotation is another technique used by organizations to attempt to motivate workers to increase productivity and

to do something different every day than the day.

7. Last, the term job enrichment defined as the process to redesing the job a worker does by giving him more to do, is another concept used in productivity improvement procedure. Job enrichment gives employees more responsibility for their work, more freedom to do their jobs therefore, production reports are made available directly to them rather than to supervisors, etc. [Ref. 10:pp. 351-368]

LIST OF REFERENCES

1. Tuttle, C.T., Productivity Measurement Methods: Classification, Critique, and Implication for the Air Force, Air Force Human Resources Laboratory, Texas, 1981.

2. Samanth, J.D. and Hassam, Z.M., "Productivity Measurement in Manufacturing Companies by using a Product-Oriented Total Productivity Model", Proceedings, Spring Annual Conference, Atlanta, Georgia, 1980.

3. Katzell, R.A., Yankelovich, D., Fein, M., Ornati, D.A., and Nash, A., Work, Productivity and Job Satisfaction, New York: The Psychological Corporation, 1975.

4. Herrick, N.Q., The Quality of Work and its Outcomes: Estimating Potential Increases in Labor Productivity, Columbus, OH: Academy for Contemporary Problems, 1975.

5. Pavlopoulos P., Microeconomic Theory, Volume One, Saccoula, 1976.

6. Aedo, M.E., An Aid for the Allocation of Resources in Ship Repairs at Naval Shipyards, Master's Thesis, Naval Postgraduate School, Monterey, California, 1974.

7. Grahlman, B.R., Methodology for Benefit Analysis of CAD/CAM in USN Shipyards, Master's Thesis, Naval Postgraduate School, Monterey, California, 1984.

8. Karadag, O., An Algorithm for Scheduling a Ship's Force During a Shipyard Overhaul, Master's Thesis, Naval Postgraduate School, Monterey, California, 1980.

9. Kendrick, W.J., Understanding Productivity : An Introduction to the Dynamics of Productivity Change, Johns Hopkins University Press, 1977.

10. Aft, S.L., Productivity, Measurement and Improvement, Reston, 1983.

11. Hays, W.L., Quantification in Psychology, Belmont, California: Brooks/Cole Publishing Company, 1967.

12. Conover, W.J., Practical Nonparametric Statistics, Wiley, 2nd Edition 1980.

13. Nebeker, M.D., Neuberger, M.B., Hulton, N.V., Productivity Improvement in a Purchasing Division :

[illegible] of a Performance Contingent Reward System (PCRS), NPRDC TR 82-34, 1982.

14. Everett, E.A.Jr., and Ebert, J.R., Production and Operations Management, Prentice-Hall, 1982.

15. Stewart, T.W., "A Participative Approach to Productivity Measurement in a Manufacturing Firm", Proceedings, Spring Annual Conference, Toronto, Canada, 1978.

16. Sink, S.D., Productivity Management : Planning, Measurement and Evaluation, Control and Improvement, Wiley, 1980.

17. Bain, D., The Productivity Prescription. The Manager's Guide to Improving Productivity and Profits, McGraw-Hill, 1982.

18. Box, E.G., Hunter, G.W., Hunter, S.J., Statistics for Experimenters. An Introduction to Design, Data Analysis, and Model Building, Wiley, 1978.

19. Haravgis, J.P., A Total Factor Productivity Measurement for Aircraft Maintenance Organizations, Master's Thesis, Naval Postgraduate School, Monterey, California, 1984.

20. Hamlin, P.E., "Developments in Firm-Level Productivity Measurement", Proceedings, Spring Annual Conference, San Francisco, California, 1979.

21. Fletcher, R.O., A Productivity Measurement Model Application at an Aircraft Maintenance Facility, Master's Thesis, Naval Postgraduate School, Monterey, California, 1980.

22. Bretton, E.G., Dockstader, L.S., Nebeker, M.D., Shumate, E.C., Measurement of Productivity Enhancement: Evaluating a Performance-Contigent Reward System that uses Economic Incentives, Navy Personnel Research and Development Center, San Diego, California, 1977.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defence Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943-5002	2
3.	Department of Operations Research/ Systems Analysis, Code 55 Naval Postgraduate School Monterey, California 93943	1
4.	Professor D.E. Neil, Code 55Ni Department of Operations Research/ Systems Analysis Naval Postgraduate School Monterey, California 93943	1
5.	Professor T. . Mitchell, Code 55Ml Department of Operations Research/ Systems Analysis Naval Postgraduate School Monterey, California 93943	1
6.	Hellenic Navy General Staff Stratopedon Papagou Holargos, Athens GREECE	4
7.	LCDR Chris G. Nicolaou 86, Thiras Str. Athens 10446 GREECE	2

1835/7

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA 93943-5002

Thesis
N545 Nicolaou
c.1 Techniques for organizing and implementing a Naval base productivity improvement.

thesN545
Techniques for organizing and implementi
3 2768 000 72777 0
DUDLEY KNOX LIBRARY